SECURE REGIONAL-SCALE EARTHQUAKE GROUND MOTION PREDICTIONS THROUGH PYHSICS-BASED AND EMPIRICAL APPROACHES: A CASE STUDY CENTRAL ITALY

2024-01-30
SECURE 2024 - PLANETARY MEETING

A ML – WORKFLOW FOR SEISMIC CATALOG IMPLEMENTATION: THE L'AQUILA 2009 CASE STUDY

Rossella Fonzetti[1,2]*, Luisa Valoroso[2], Pasquale De Gori[2], Aladino Govoni[2] and Claudio Chiarabba[2]

1: Università degli Studi Roma Tre, Dipartimento di Scienze, Rome (Italy)
2: Istituto Nazionale di Geofisica e Vulcanologia, Rome (Italy)

Presented by Rossella Fonzetti*

AGU23 San Francisco, CA & Online Everywhere 11-15 December 2023

Poster presentation at AGU2023
ABSTRACT ID:131838
PAPER NUMBER: S31G-0423

**rossella.fonzetti@uniroma3.it*

ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

ROMA TRE UNIVERSITÀ DEGLI STUDI

SCIENZE Dipartimento di Eccellenza

Content:

Goals:

- Test the ML-capabilities to phase identification, picking and phase association;
- Create a new ML-seismic catalog for the L'Aquila 2009 seismic sequence.

1. Introduction:

- The L'Aquila 2009 seismic sequence.

2. Method:

- ML-modules;
- 1D-locations.

3. Results:

- The new ML-seismic catalog;
- Comparison with Valoroso et al., 2013 (LV13) catalog.

4. Next Steps:

- Training using INSTANCE;
- weights' picks tuning.

5. Conclusions:

SECURE REGIONAL-SCALE EARTHQUAKE GROUND MOTION PREDICTIONS THROUGH PHYSICS-BASED AND EMPIRICAL APPROACHES: A CASE STUDY CENTRAL ITALY

ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

ROMA TRE UNIVERSITÀ DEGLI STUDI

SCIENZE Dipartimento di Eccellenza

*rossella.fonzetti@uniroma3.it

1. Introduction:

The L'Aquila 2009 seismic sequence

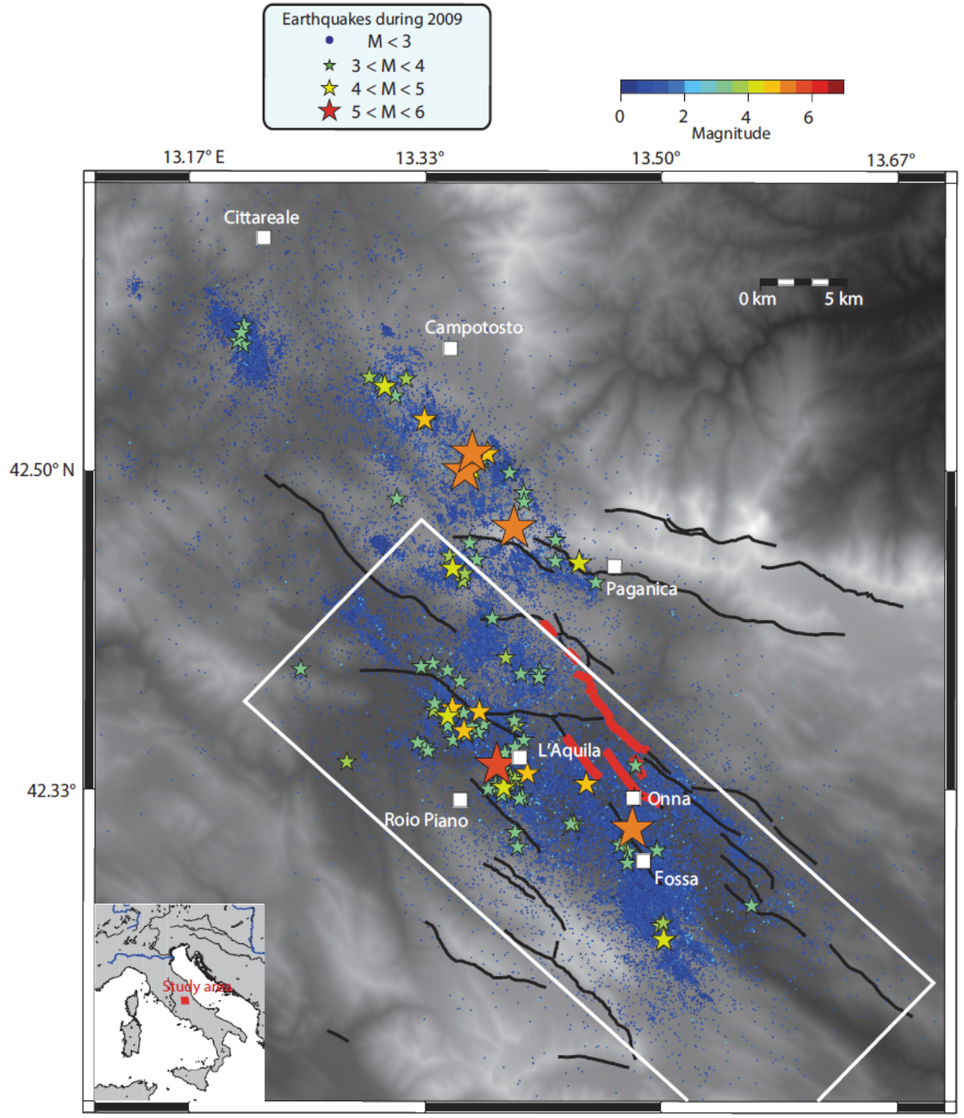


Fig - The L'Aquila 2009 seismic sequence. Seismic events are color-coded according to magnitude. The red star is the mainshock of 6th April 2009. The white box is the surface projection of the fault plane (20 km long, dips 54° to the southwest) modeled by Cirella et al., (2012) by inverting strong motion, GPS, and DInsar data. Black lines represent traces of the active mapped faults and co-seismic surface ruptures (red lines) [after Boncio et al., 2010].

- The 6th April (01:32 UTC) 2009 Mw 6.1 normal faulting earthquake developed along the Paganica fault.
- Mw 4.1 foreshock and a swarm started on March 30th (Chiaraluce et al. 2011).

The Goals:

1. New seismic catalog throught ML-methods for the entire 2009 year;
2. Comparison with Valoroso et al., 2013 (LV13) catalog obtained with semi-automatic procedures (Aldersons, 2004).

SECURE REGIONAL-SCALE EARTHQUAKE GROUND MOTION PREDICTIONS THROUGH PHYSICS-BASED AND EMPIRICAL APPROACHES: A CASE STUDY CENTRAL ITALY

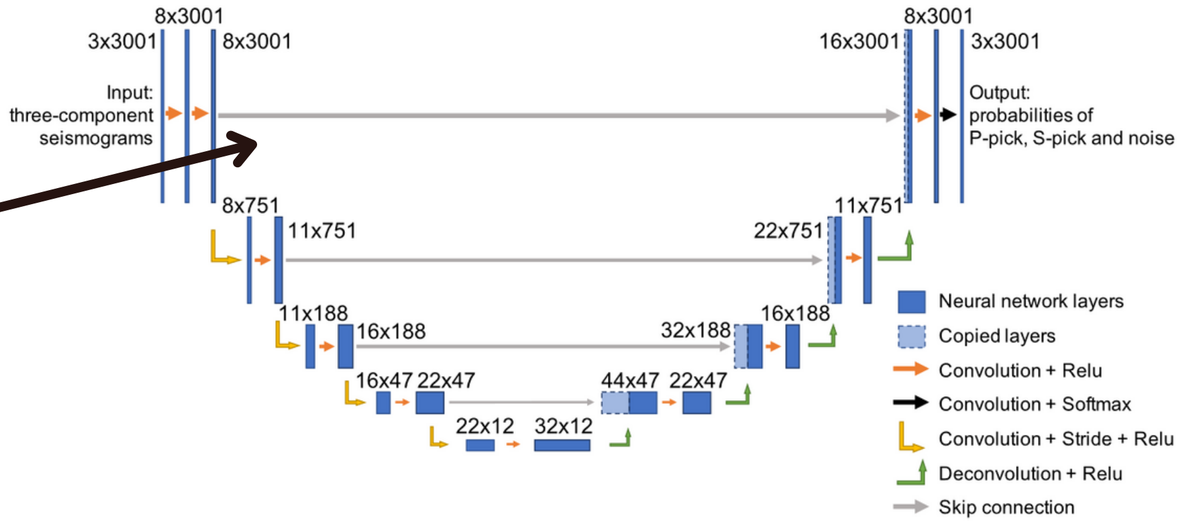
ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA · ROMA TRE UNIVERSITÀ DEGLI STUDI · SCIENZE Dipartimento di Eccellenza

*rossella.fonzetti@uniroma3.it

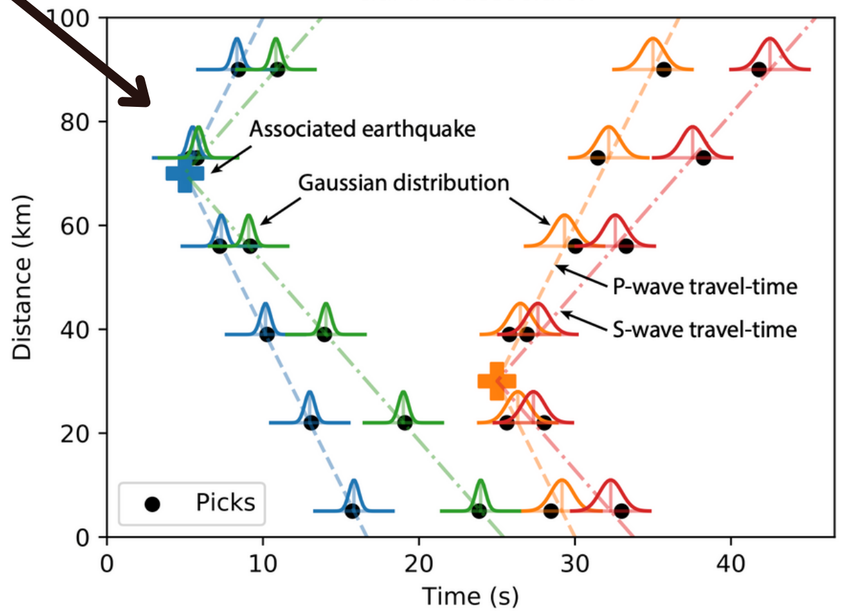
2. Method:

- PhaseNet (Zhu et al., 2018): picks P- and S-arrival times;
- GaMMA (Zhu et al., 2022): association, location and magnitude estimation;
- 1D-locations by means of Hypoellipse (Lahr,1999);

The Deep Neural Network (DDN) PhaseNet architecture.



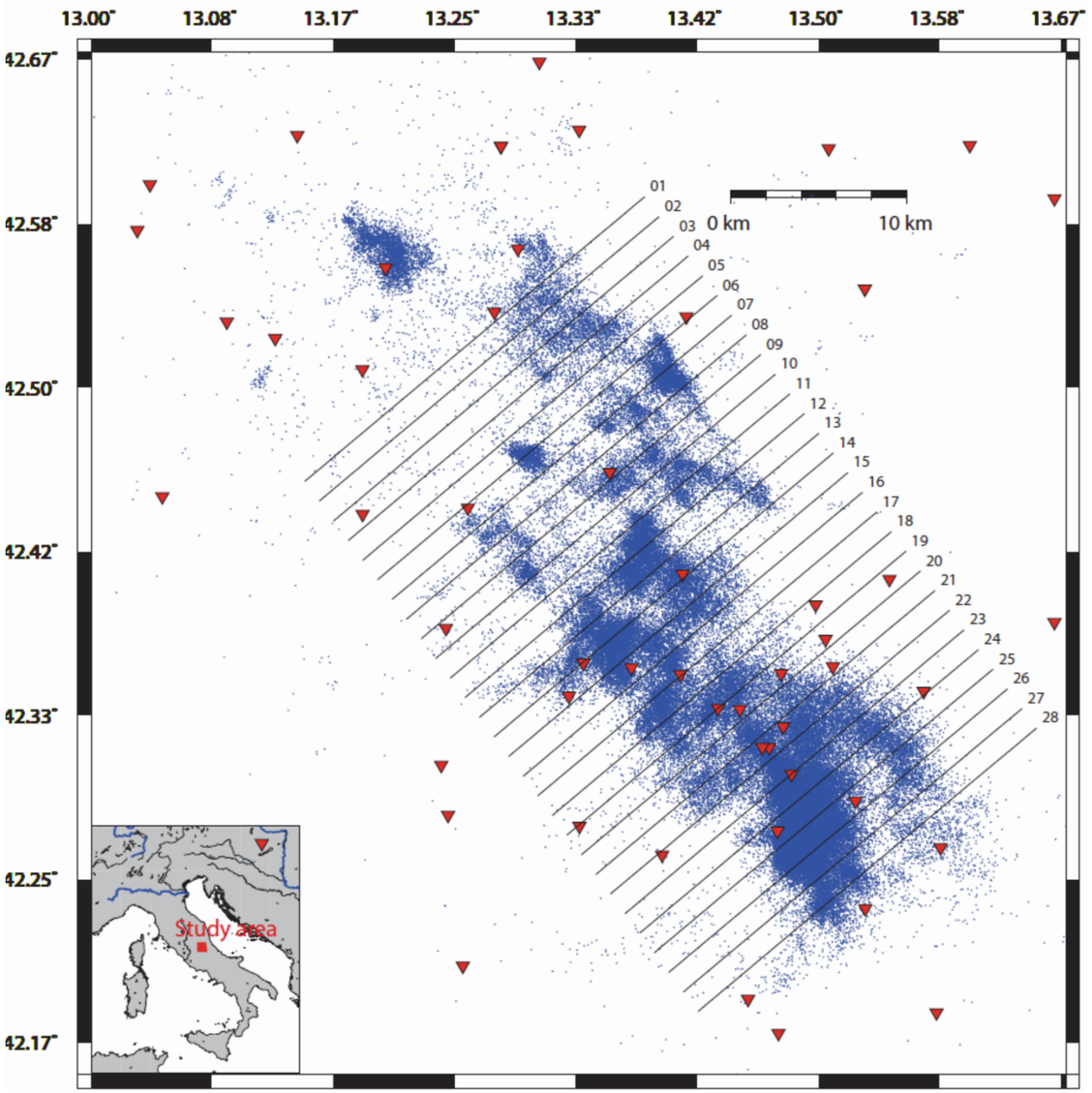
GaMMA associator.



*rossella.fonzetti@uniroma3.it

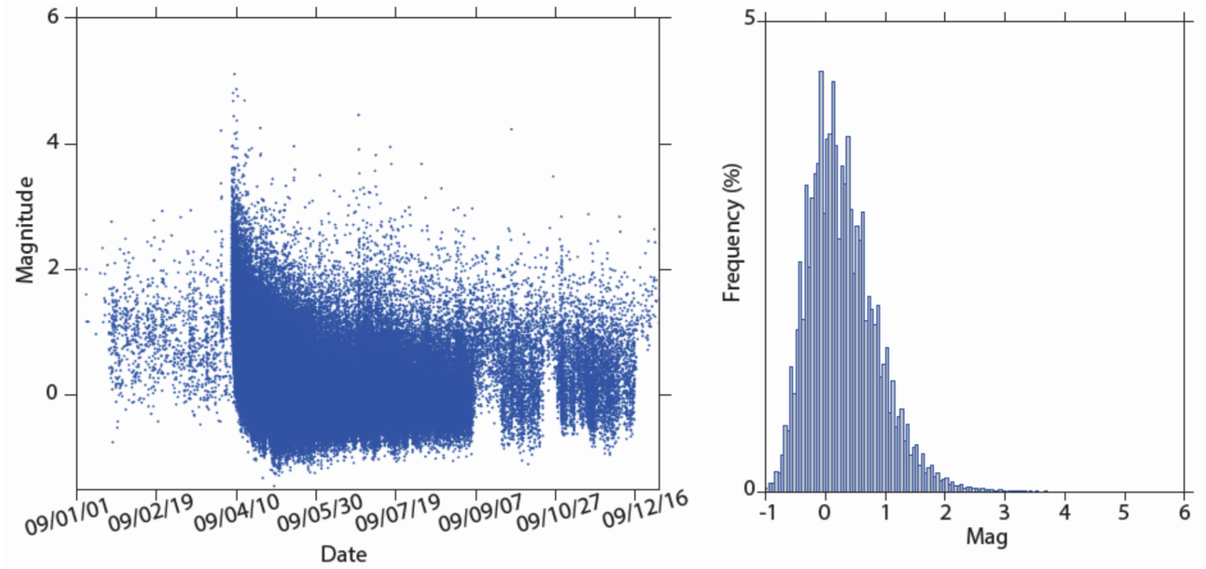
3. Results: The new ML–catalog– 1D relocations

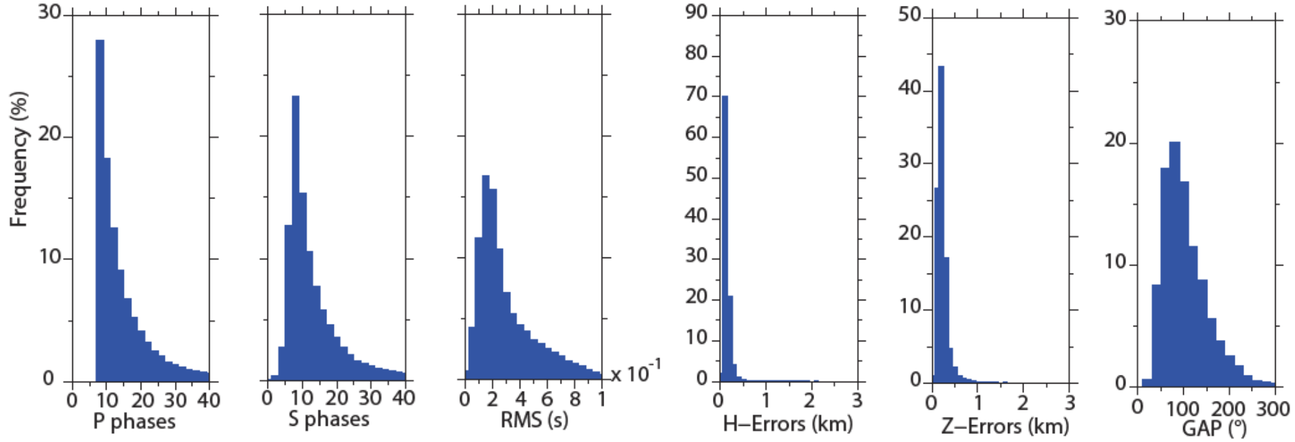
- 90 seismic stations (70 from INGV and 20 from RESIF);
- about 335,809 seismic events only during 2009 year (85% more than Valoroso et al., 2013 catalog);
- Only 6 P- and 4- S waves arrival times = 221, 634 seismic events;
- All the picks weights fixed at 0;
- 1D- location by means of Hypoellipse (Lahr, 1999) using an ad-hoc velocity model;
- 111,037 seismic events with RMS < 0.4 s; ERH < 0.1 km and ERZ < 0.2 km.

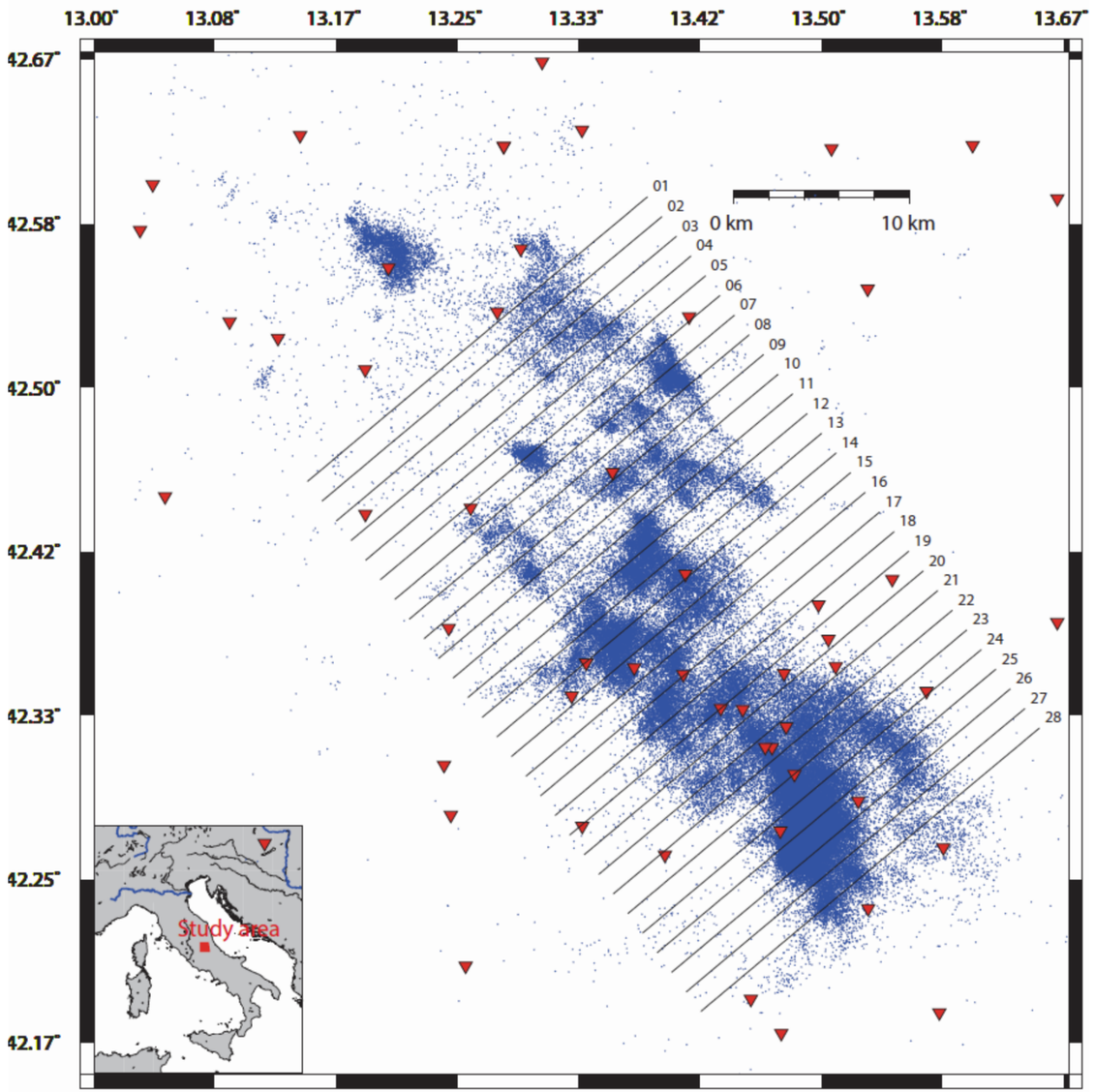


*rossella.fonzetti@uniroma3.it

3. Results: The new ML–catalog– 1D relocations







SECURE REGIONAL-SCALE EARTHQUAKE GROUND MOTION PREDICTIONS THROUGH PHYSICS-BASED AND EMPIRICAL APPROACHES: A CASE STUDY CENTRAL ITALY

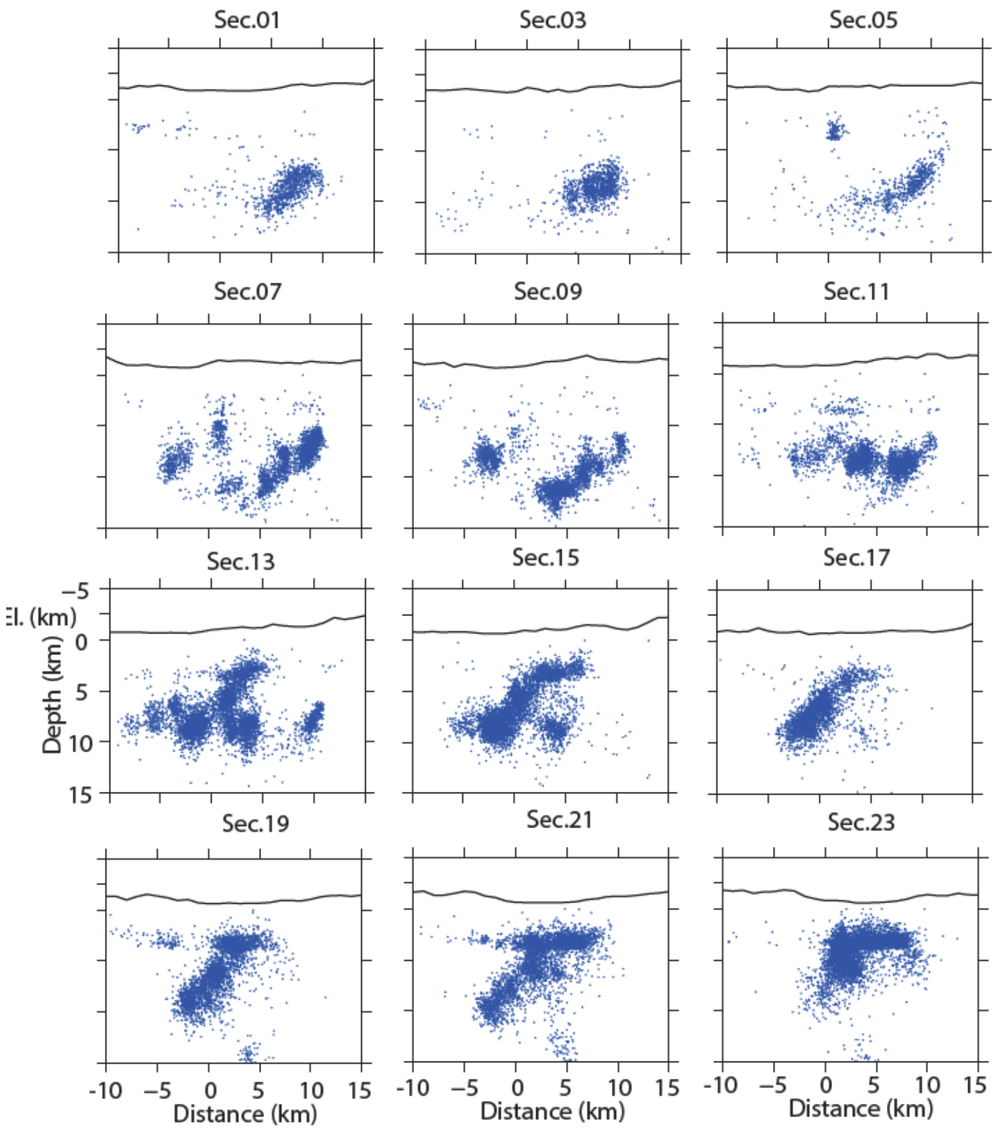
ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

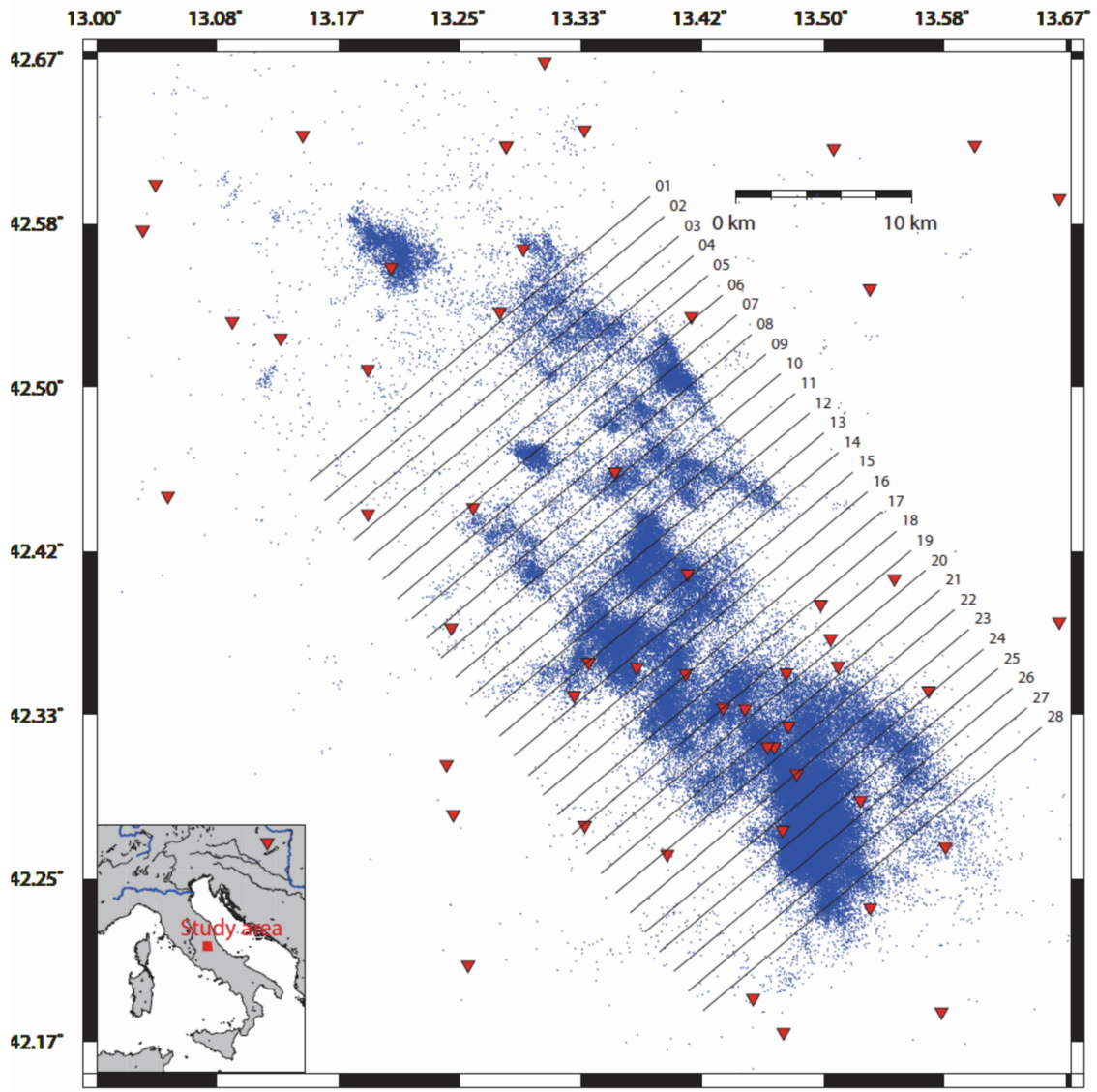
ROMA TRE UNIVERSITÀ DEGLI STUDI

SCIENZE Dipartimento di Eccellenza

*rossella.fonzetti@uniroma3.it

3. Results: The new ML-catalog- 1D relocations





SECURE REGIONAL-SCALE EARTHQUAKE GROUND MOTION PREDICTIONS THROUGH PHYSICS-BASED AND EMPIRICAL APPROACHES: A CASE STUDY CENTRAL ITALY

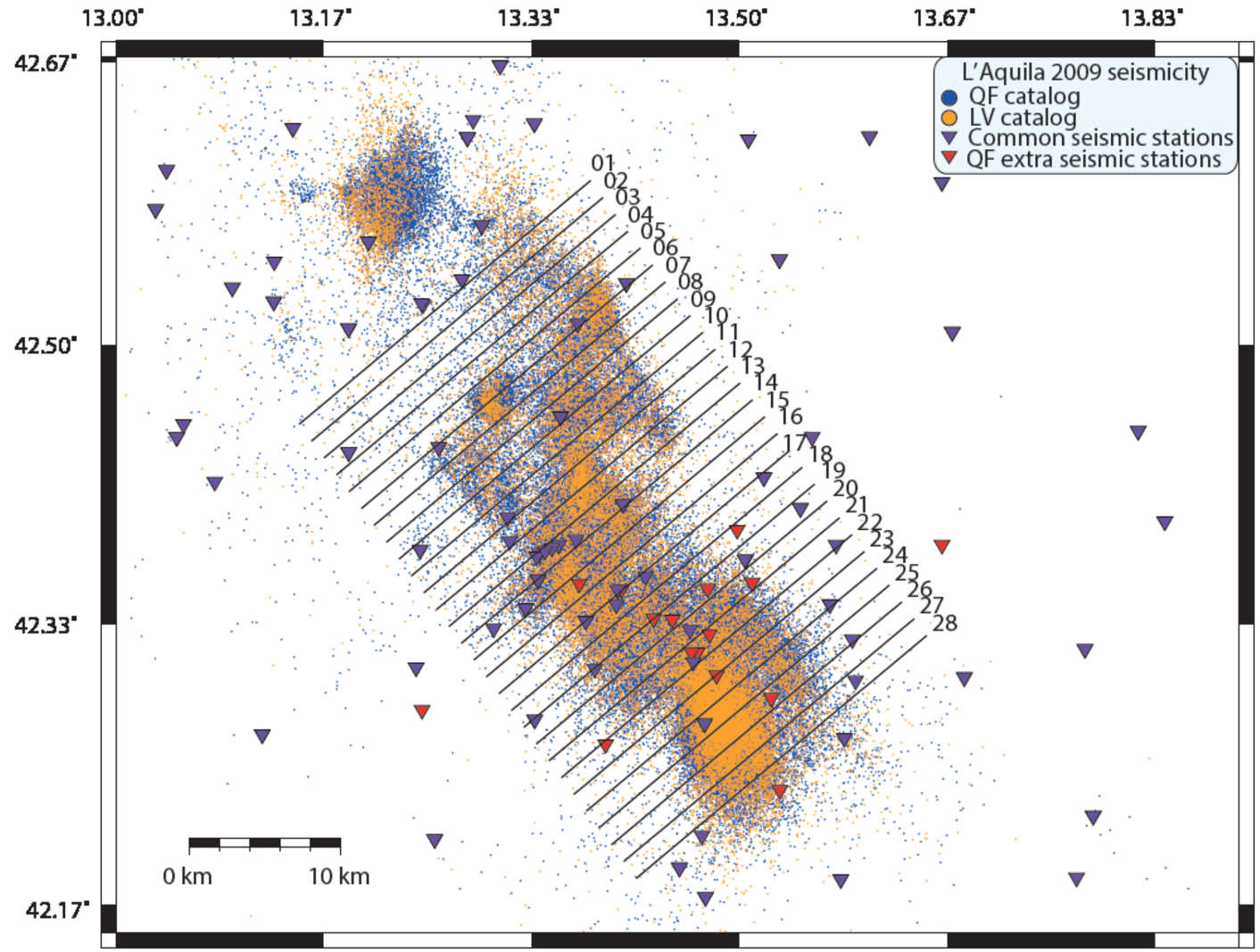
ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

ROMA TRE UNIVERSITÀ DEGLI STUDI

SCIENZE Dipartimento di Eccellenza

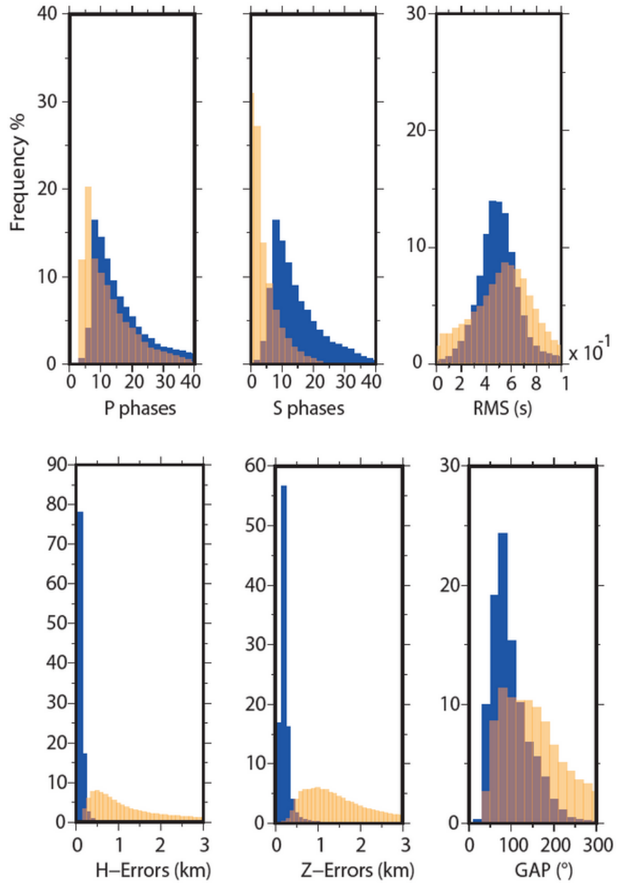
*rossella.fonzetti@uniroma3.it

3. Results: Comparion with LV13 Catalog



74,243 seismic events with: RMS ⩽ 0.6 s; ERH ⩽ 1.0 km and ERZ ⩽ 2.0 km

33,378 seismic events with: RMS ⩽ 0.6 s; ERH ⩽ 1.0 km and ERZ ⩽ 2.0 km



SECURE REGIONAL-SCALE EARTHQUAKE GROUND MOTION PREDICTIONS THROUGH PHYSICS-BASED AND EMPIRICAL APPROACHES: A CASE STUDY CENTRAL ITALY

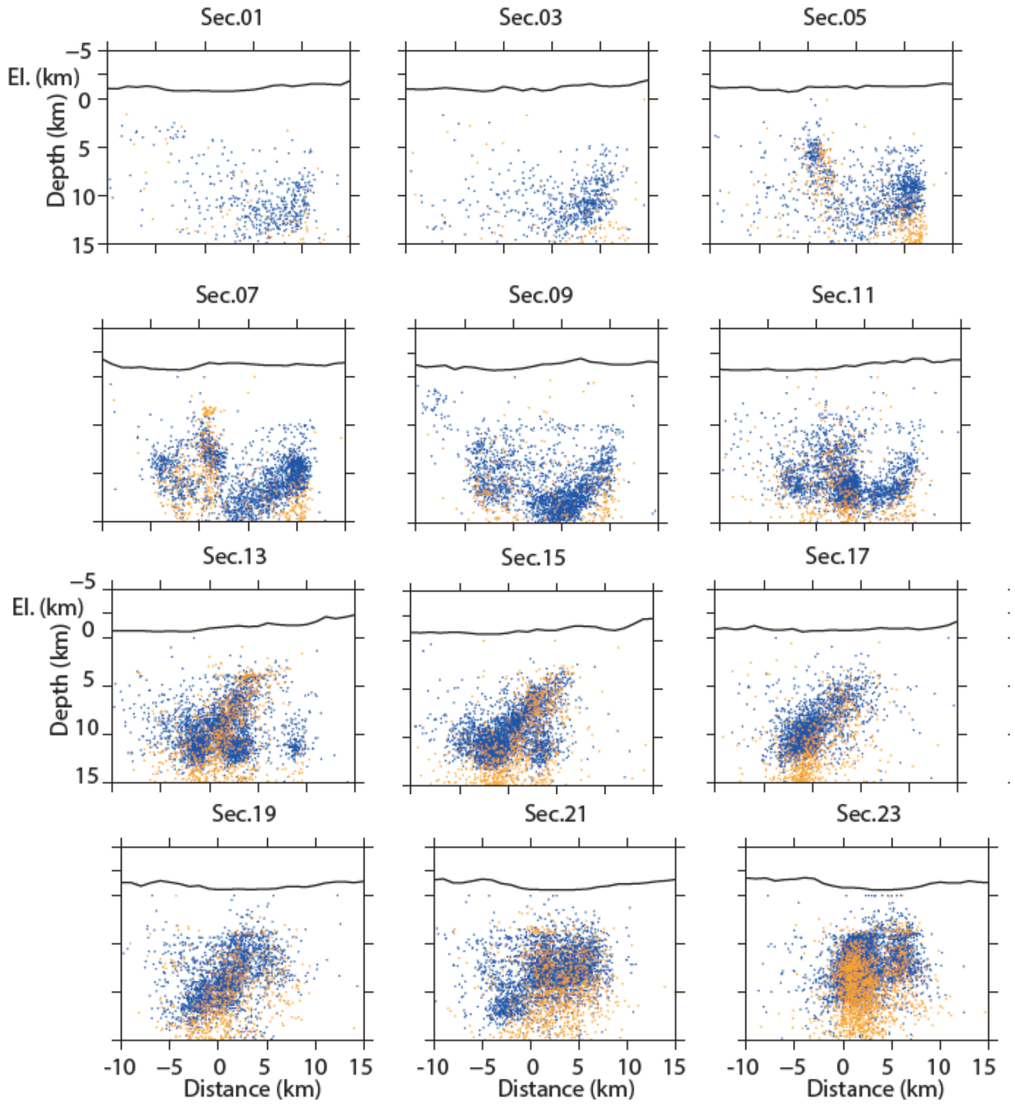
ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

ROMA TRE UNIVERSITÀ DEGLI STUDI

SCIENZE Dipartimento di Eccellenza

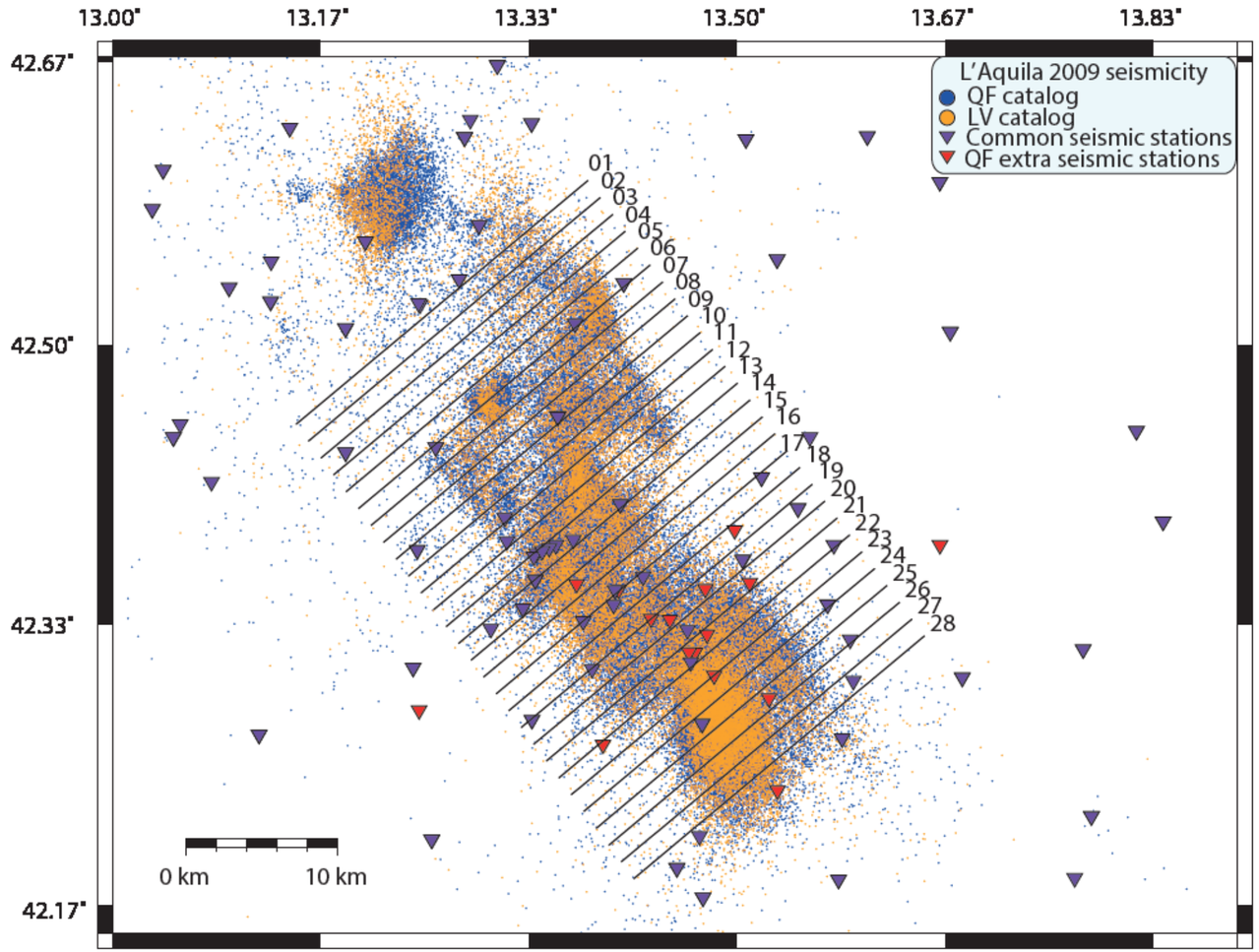
*rossella.fonzetti@uniroma3.it

3. Results: Comparion with LV13 Catalog



74,243 seismic events with:
RMS ⩽ 0.6 s; ERH ⩽ 1.0 km
and ERZ ⩽ 2.0 km

33,378 seismic events with:
RMS ⩽ 0.6 s; ERH ⩽ 1.0 km
and ERZ ⩽ 2.0 km



SECURE REGIONAL-SCALE EARTHQUAKE GROUND MOTION PREDICTIONS THROUGH PHYSICS-BASED AND EMPIRICAL APPROACHES: A CASE STUDY CENTRAL ITALY

ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

ROMA TRE UNIVERSITÀ DEGLI STUDI

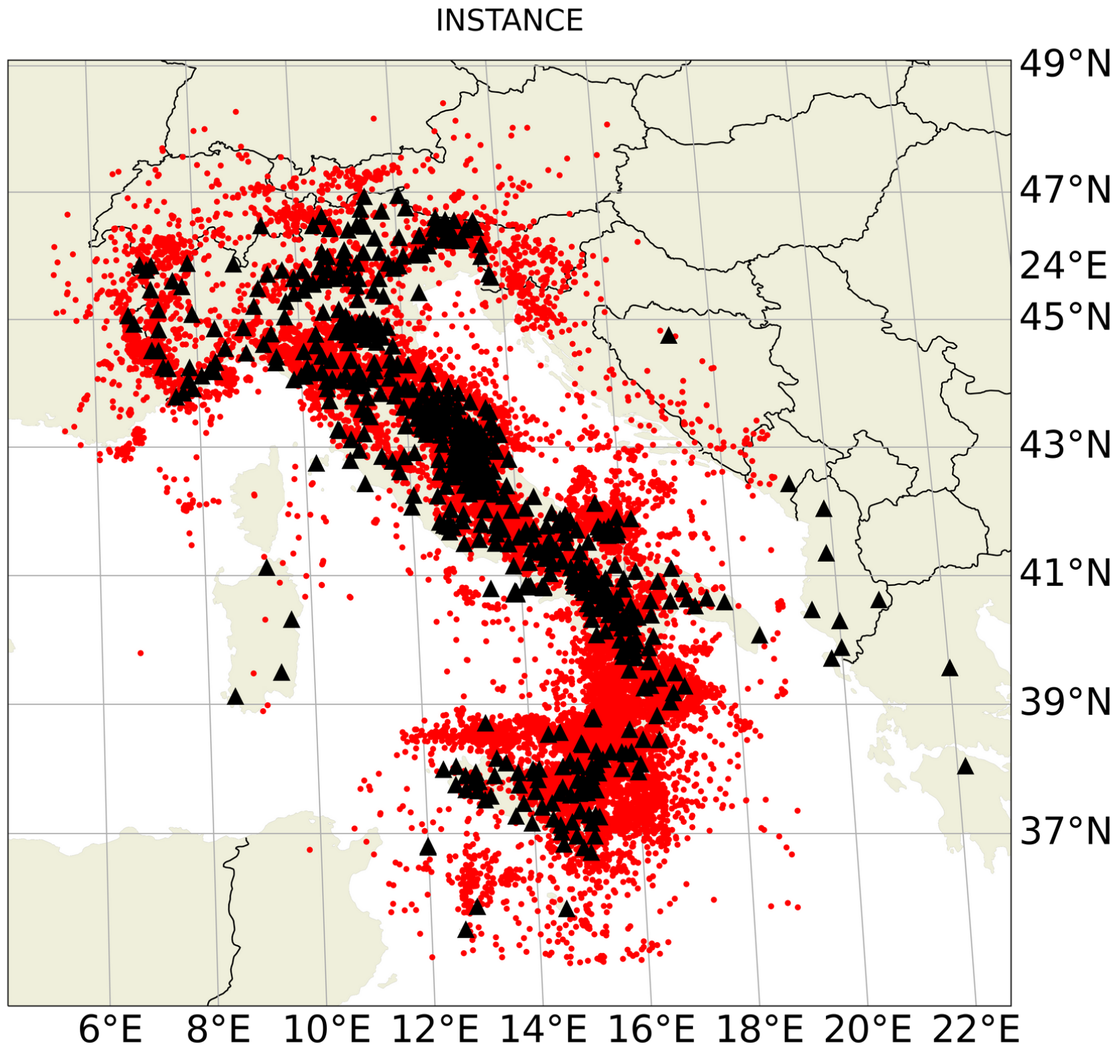
SCIENZE Dipartimento di Eccellenza

*rossella.fonzetti@uniroma3.it

4. Next Steps:

Work in progress ..

- Double difference (DD) relocations using HypoDD software (Waldhauser, 2001);
- DD- seismic tomography using TomoDD software (Zhang, 2003);
- Training using INSTANCE DATASET (Michelini et al., 2021);
- Convert the PhaseNet probability distribution into P- and S- waves weights.

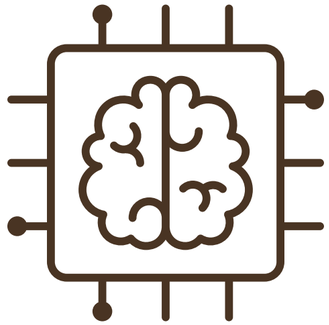


SECURE REGIONAL-SCALE EARTHQUAKE GROUND MOTION PREDICTIONS THROUGH PHYSICS-BASED AND EMPIRICAL APPROACHES: A CASE STUDY CENTRAL ITALY

ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA · ROMA TRE UNIVERSITÀ DEGLI STUDI · SCIENZE Dipartimento di Eccellenza

*rossella.fonzetti@uniroma3.it

5. Conclusion:



- Thanks to ML- picks and associator the number of seismic events that occurred during 2009 year increased of about 85%.

- The new seismic catalog is composed of about 221,000 seismic events (best 1D-locations).

*rossella.fonzetti@uniroma3.it

SECURE REGIONAL-SCALE EARTHQUAKE **GROUND MOTION PREDICTIONS** THROUGH PYHSICS-BASED AND EMPIRICAL APPROACHES: **A CASE STUDY CENTRAL ITALY**

2024-01-30
SECURE 2024 - PLANETARY MEETING

Thank you!

Do you have any questions?

rossella.fonzetti@unrimoma3.it

References:

- Aldersons, F., 2004. Toward a three-dimensional crustal structure of theDead Sea region from local earthquake tomography,PhD thesis,Tel AvivUniversity, Israel, 120 pages. http://faldersons.ne
- Lahr, J. C. (1999). HYPOELLIPSE: A computer program for determining local earthquake hypocentral parameters, magnitude, and first motion pattern (p. 119). Reston, VA: US Geological Survey.
- Michelini, A., Cianetti, S., Gaviano, S., Giunchi, C., Jozinović, D., & Lauciani, V. (2021). INSTANCE–the Italian seismic dataset for machine learning. Earth System Science Data, 13(12), 5509-5544.
- Valoroso, L., Chiaraluce, L., Piccinini, D., Di Stefano, R., Schaff, D., & Waldhauser, F. (2013). Radiography of a normal fault system by 64,000 high-precision earthquake locations: The 2009 L'Aquila (central Italy) case study. Journal of Geophysical Research: Solid Earth, 118(3), 1156-1176.
- Valoroso, L., Chiaraluce, L., & Collettini, C. (2014). Earthquakes and fault zone structure. Geology, 42(4), 343-346.
- Zhu, W., & Beroza G. B. (2019). PhaseNet: A Deep-Neural-Network-Based Seismic Arrival Time Picking Method. Geophysical Journal International, 216(1), 261-273.
- Zhu, W., McBrearty, I. W., Mousavi, S. M., Ellsworth, W. L., & Beroza, G. C. (2022). Earthquake phase association using a Bayesian Gaussian mixture model. Journal of Geophysical Research: Solid Earth, 127(5), e2021JB023249.

ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

ROMA TRE UNIVERSITÀ DEGLI STUDI

SCIENZE Dipartimento di Eccellenza