WP1- Enhancements of Existing Crustal Velocity Models and Seismic Datasets

Vp and Vp/Vs tomographic model of the three target regions of the SECURE project: state of the art and work in progress.

P. De Gori &
WP 1.1 team
INGV

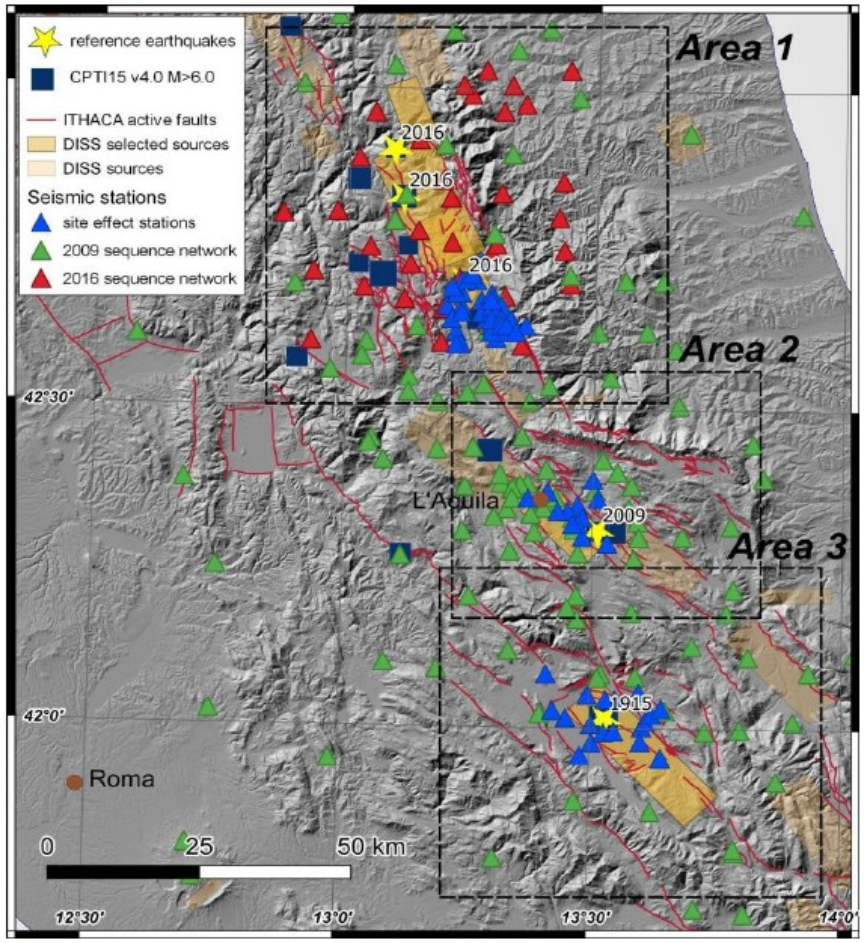
WP1- Enhancements of Existing Crustal Velocity Models and Seismic Datasets

WP1.1 is aimed to compute detailed 3D velocity models of the crustal volumes that will act as the elastic medium for the propagation of seismic waves used for simulating ground motion.

WP1.2 is focused on the determination of strong motion and macroseismic datasets necessary for testing the results of ground motion scenarios.

WP1- Enhancements of Existing Crustal Velocity Models and Seismic Datasets

The three selected target areas:
Amatrice-Visso-Norcia (AREA1)
L'Aquila (AREA2)
Fucino basin (AREA3)



For the reconstruction of 3D velocity models for the crustal volume of the the three selected fault systems we integrate the following informations:

SHALLOW STRUCTURE

a) shallow near-surface structures (basins and topography) from geological and geophysical investigations. Geometry of reflectors of seismic profiles for the shallow structure.

CRUSTAL STRUCTURE DOWN TO THE SEISMOGENIC DEPTH

b) seismic tomography models (Vp, Vs) computed by the traveltimes inversion of aftershocks or background seismicity (grid spacing at kilometric scale, i.e. 5x5x3 km)

DEEP CRUST AND UPPER MANTLE

c) we consider the possibility to include the velocity models of large scale investigations carried out in Italy (Di Stefano and Ciaccio 2014, Menichelli et al., 2023) to define the deepest portion of the target regions (lower crust + upper mantle)

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The final 3D velocity model (Vp, Vs) is interpolated with a grid spacing of ~ 200-300 m in X-Y and Z directions down to the seismogenic depths. Integration with the shallow structures.

The velocity values are integrated with density, Qp and Qs.

The final model is then transformed in “p-file” for the application of seismic wave modeling.

This file represents the medium characteristic to propagate the waveforms and to simulate the ground motion.

A first application of this procedure has been applied for the ground motion simulation of the Mw 6.5 Norcia earthquake (Arben et al., 2021)

AREA1: AVN Tomographic Model

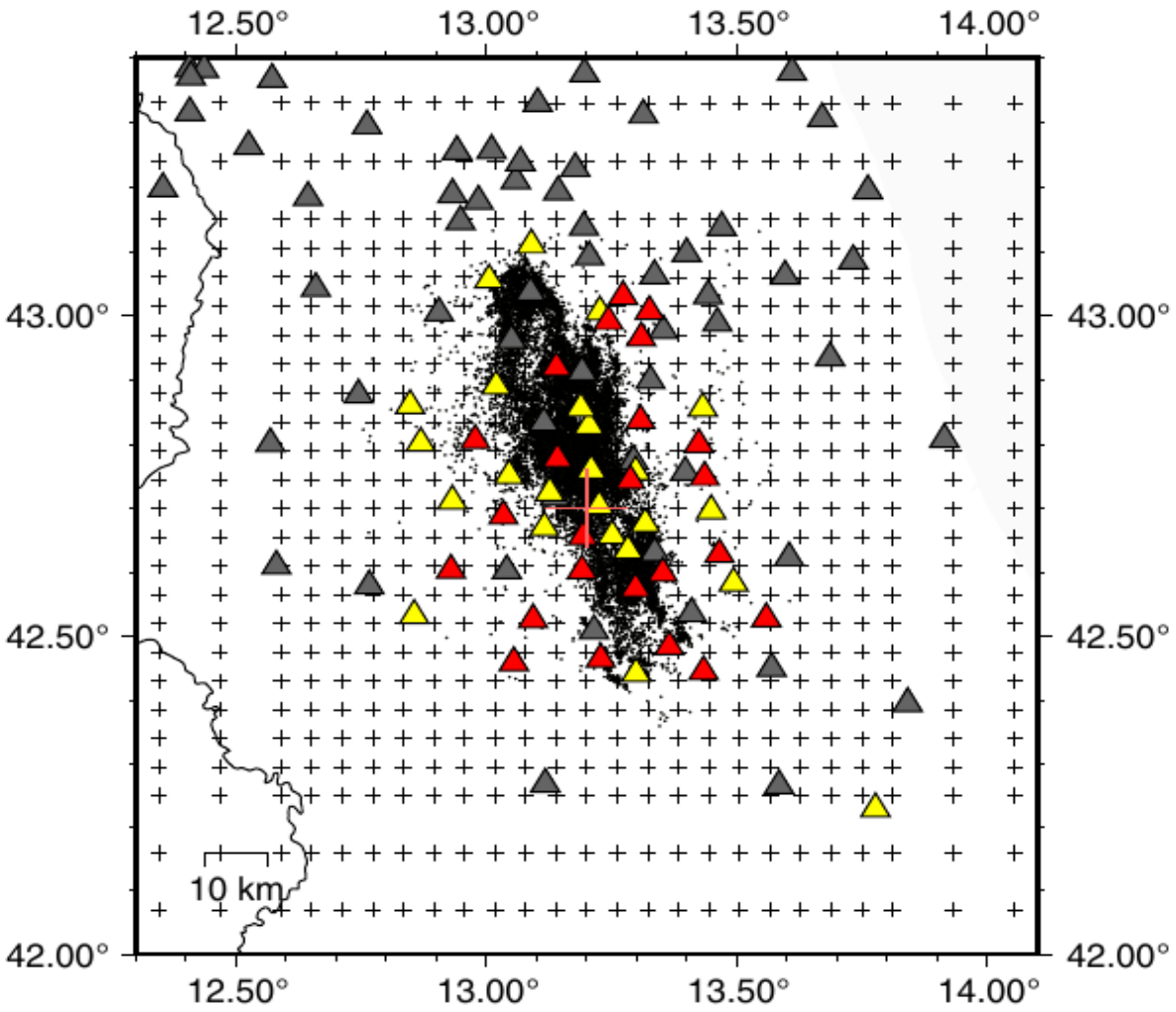
Three-component seismograms (on permanent and mobile stations) are automatically analyzed to determine the P and S wave phases for earthquake detection by using the CASP algorithm (Spallarossa et al., 2021).

The arrival times of aftershocks are inverted to obtain the velocity models (Vp,Vs) and the final locations of seismicity (code Simulps14; Haslinger, 1998).

This model in an update version of the first model of Chiarabba et al., 2018, already used for the first application of the deterministic 3D ground motion simulations (Pitarka et al., 2021)

We use a more complete set of data including arrivals from 20 additional seismic stations located within 30 km of distance from the epicentral area

Earthquakes- Seismic stations – Grid nodes



De Gori et al., 2023, SRL

Eqks = 25876

August 2016-August 2017

Picks P + S (CASP)

P=799,588 obs +
S=620,352 obs

Mobile Stations = 48

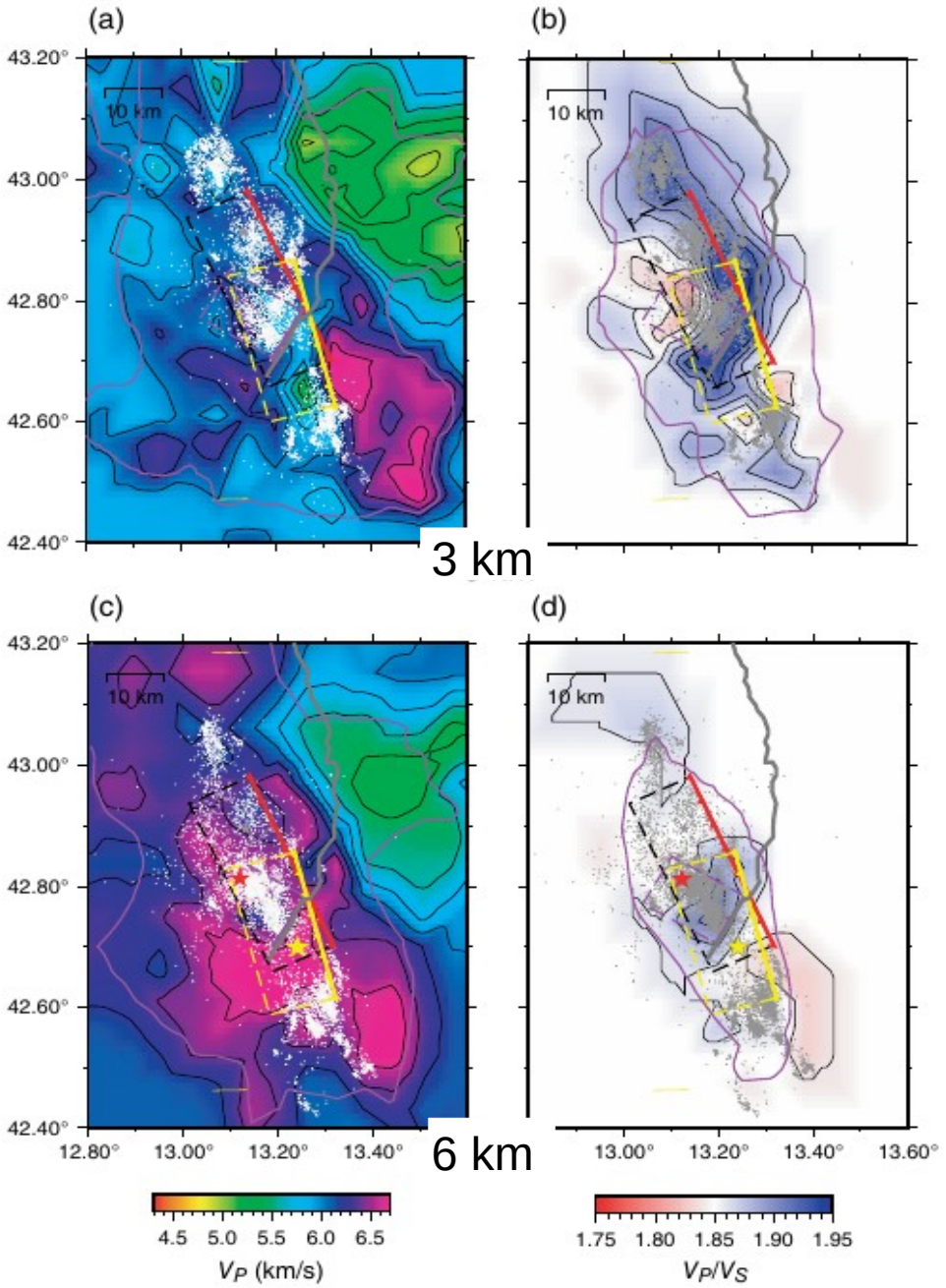
24 (INGV-yellow)

24 (BGS-red)

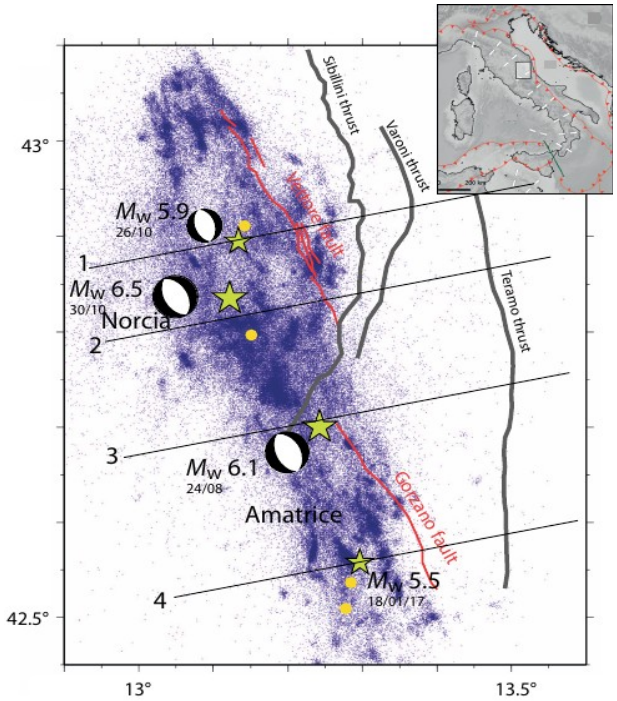
Tomo Grid
5 x 5 x 3 km

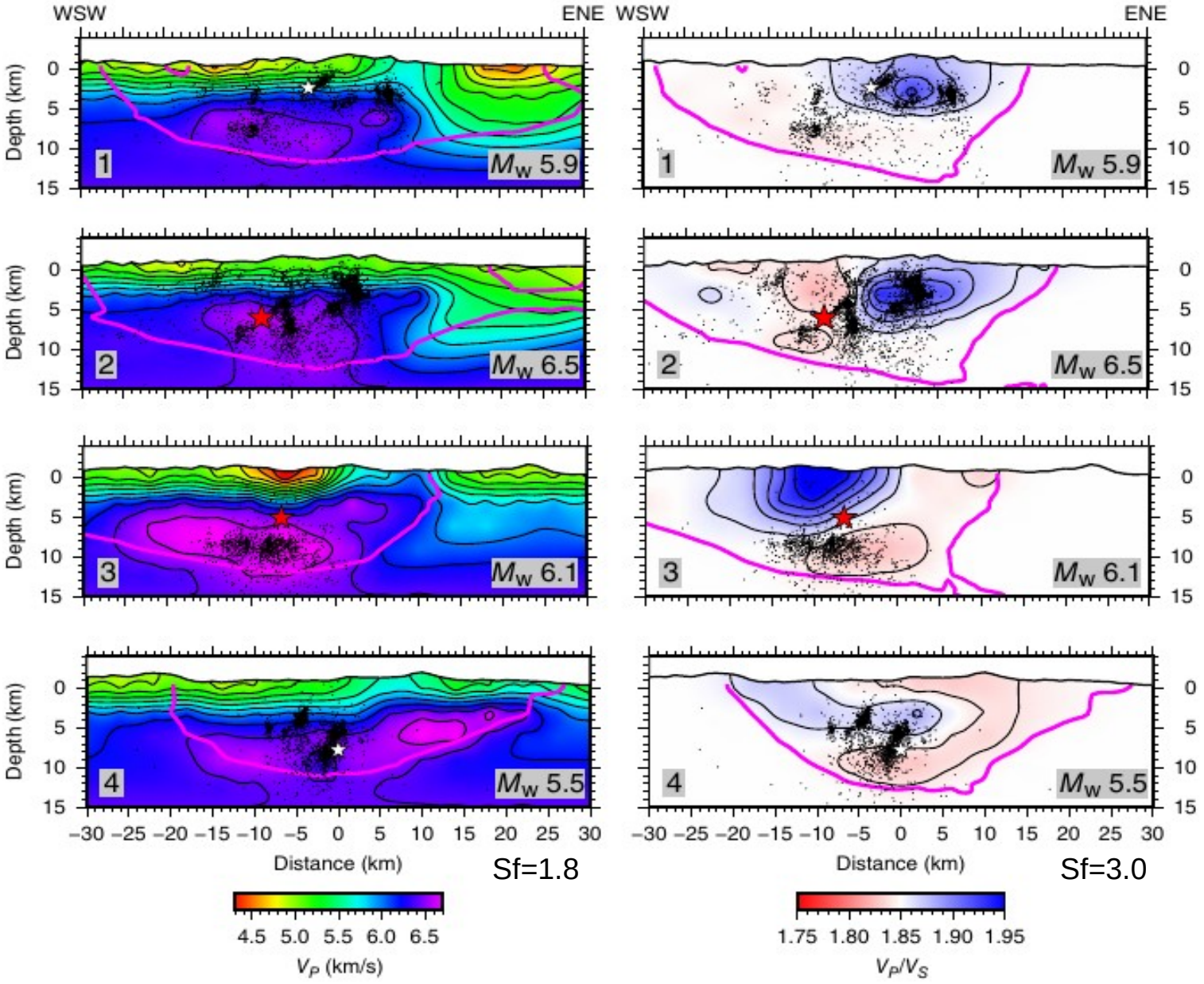
Layer depths
(0-3-6-9-12-15 km)

Horizontal maps

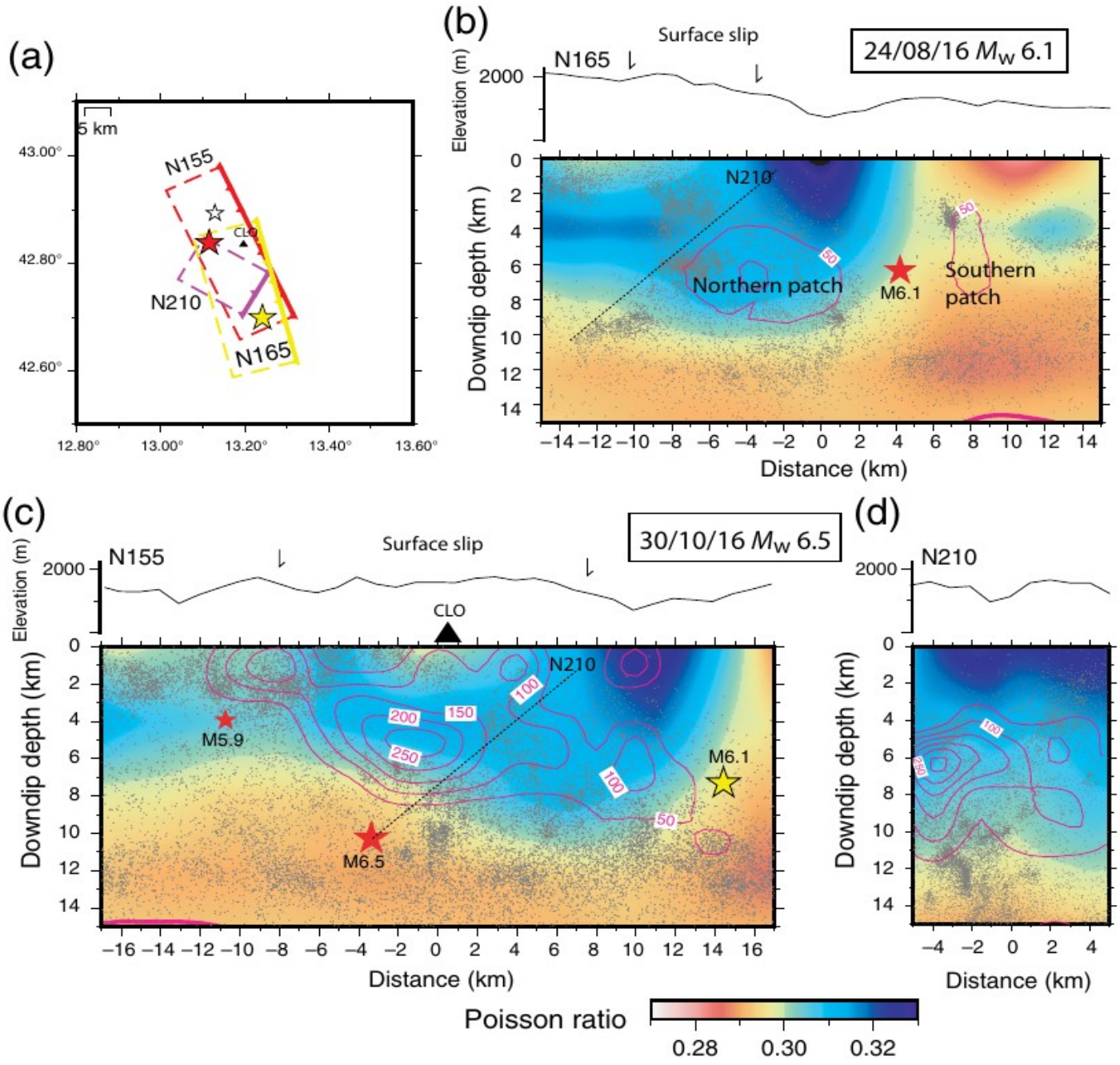


Vertical cross-sections

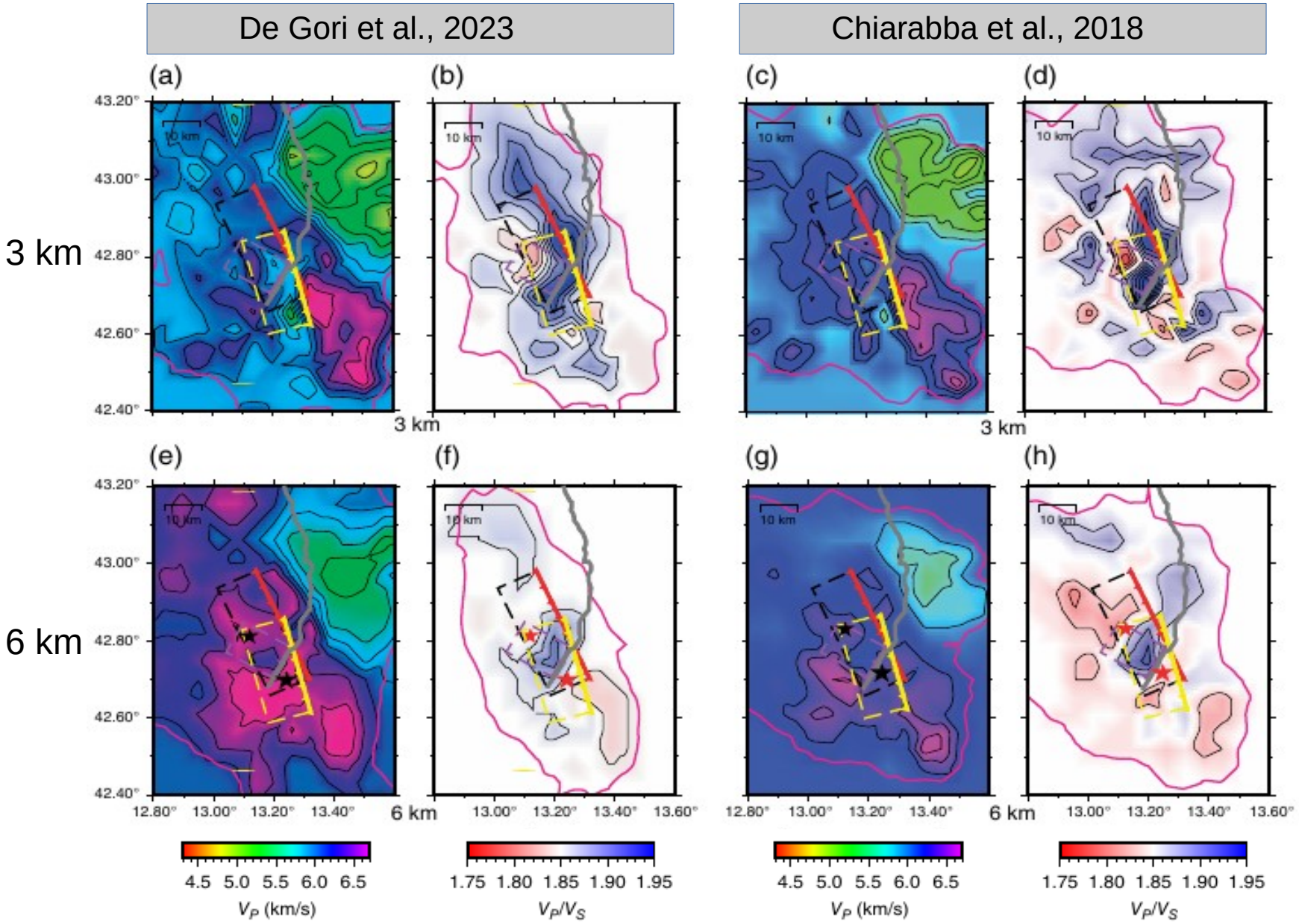




Downdip sections



Comparison between models



Tomographic Vp and Vp/Vs versus lithologies

High Vp (around 6 km/s) and high Vp/Vs (>1.90) zones correspond to fractured carbonates (Umbria-Marche succession) with high pore fluid pressure

Very high Vp (> 6.5 km/s) and ordinary Vp/Vs (around 1.80) at about 9 km depth might indicate:

a) triassic dolostone and evaporites (Burano fm) (ordinary Vp/Vs suggests fracture closing effects due to lithostatic loading and/or ductile deformation in the evaporites)

b) mafic basement (this is in contrast with the absence of significant magnetic anomalies)

AREA2: L'AQUILA 2009 FAULT SYSTEM

Three-component seismograms recorded during the L'Aquila 2009 sequence from permanent and mobile stations (40) are automatically analyzed by the code MannekenPix (Alderson et al., 2009) to determine the P and S wave arrival times.

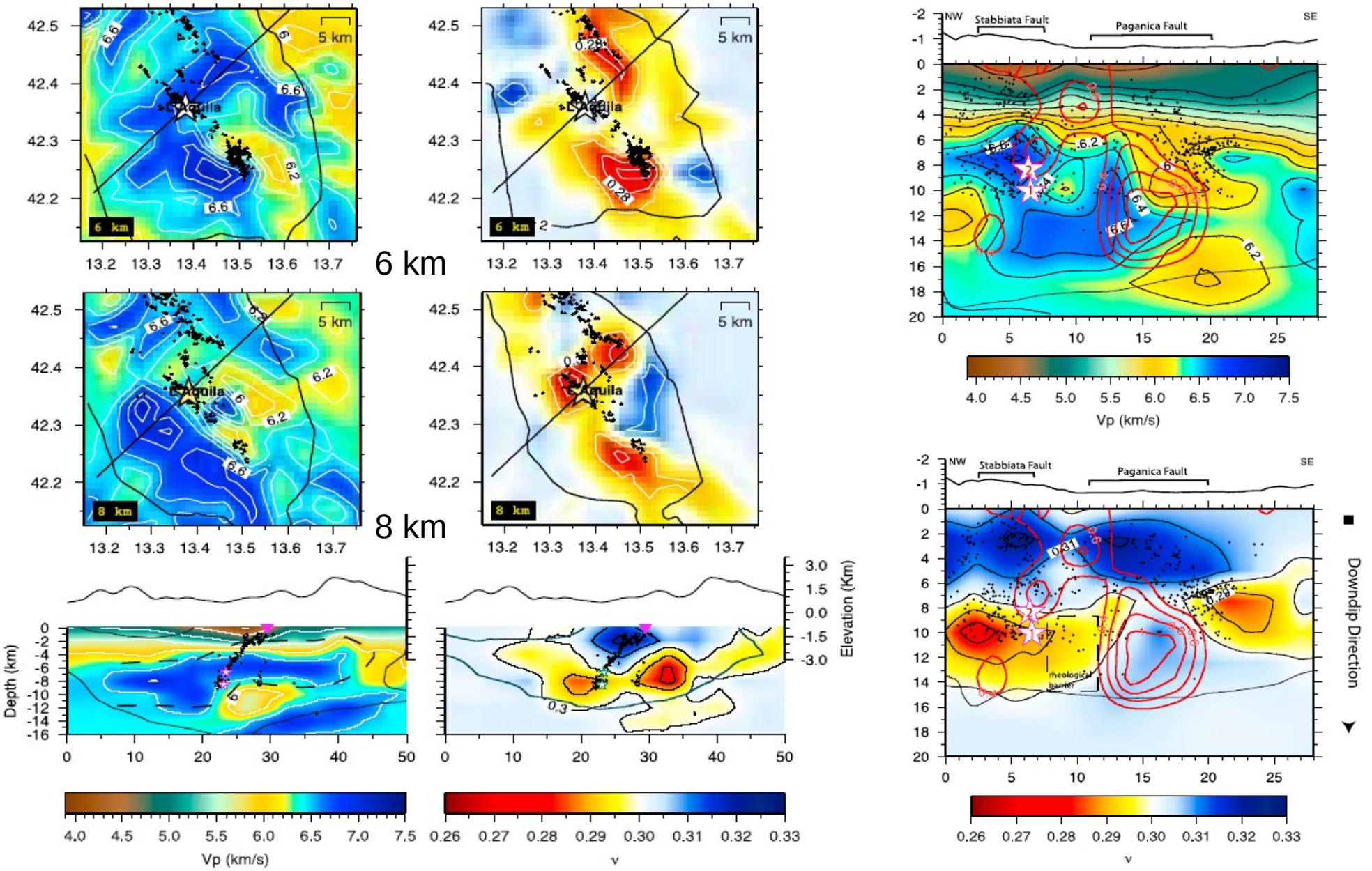
MannekenPix was first developed to read P waves on vertical components (Di Stefano et al., 2006) and subsequently completed to get P and S arrival times on 3C seismograms.

The complete MPX dataset has been mainly used to delineate the geometry of the fault system (Chiaraluce et al, 2011; Valoroso et al., 2013, Valoroso et al., 2014)

AREA2: L'AQUILA 2009 FAULT SYSTEM

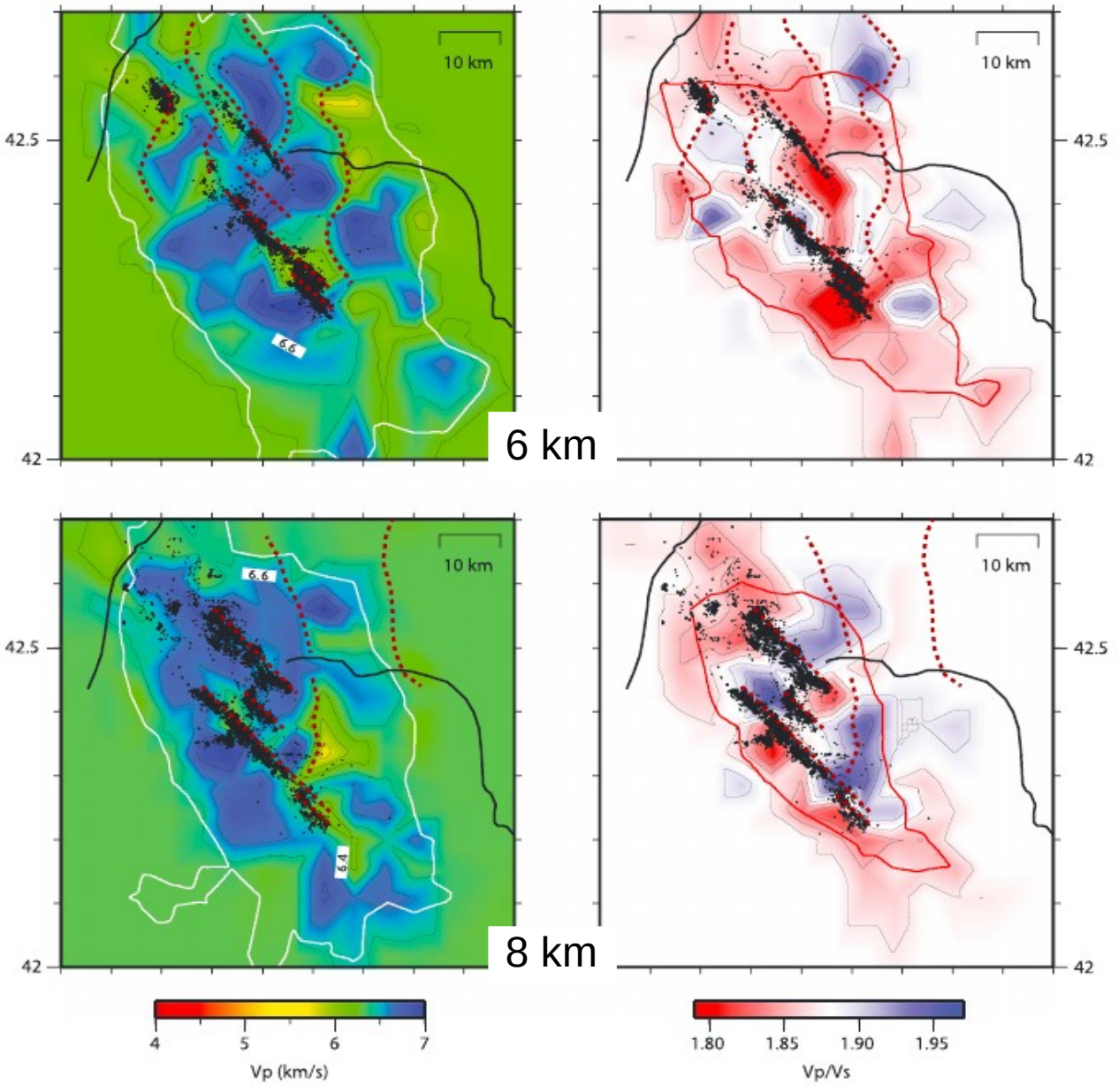
Di Stefano et al., 2011 + Buttinelli et al., 2018	LET model obtained by the inversion of the arrival times of 1300-2000 events occurred in the first 3 months of the sequence, manually picked, on permanent (17) and temporary (40) seismic stations.
Baccheschi et al., 2020	Time lapse tomography of the preparatory phase of Mw 6.1 by using the Abruzzo regional stations data (foreshocks+ early aftershocks): dataset from January to April 7, 2009
Chiarabba et al., 2022	Time lapse tomography focused on the estimation of the amounts fluids expelled from the area of large coseismic slip: dataset from April to May 2009

AREA2: L'AQUILA 2009 FAULT SYSTEM



(Di Stefano et al., 2011)

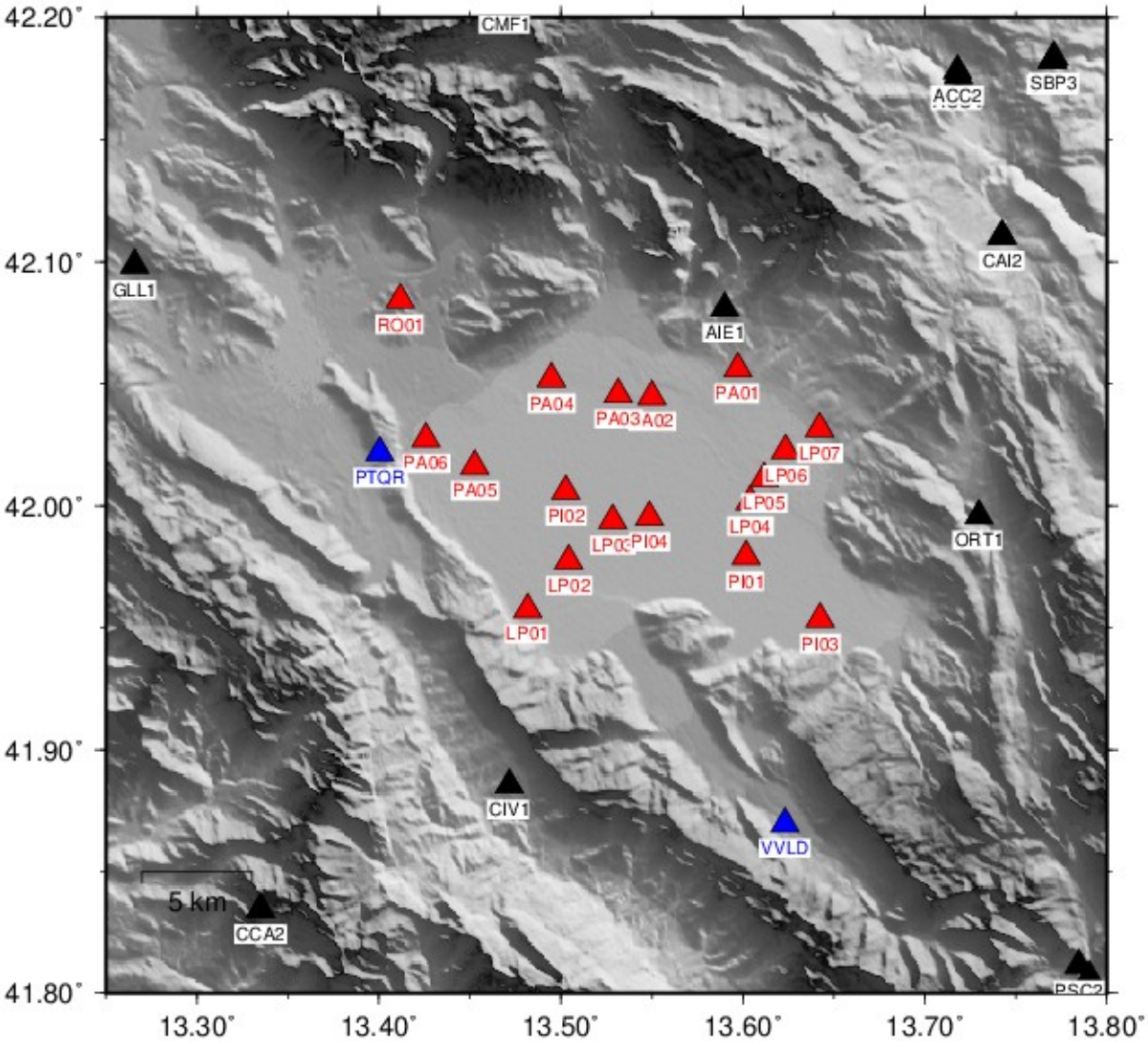
AREA2: L'AQUILA 2009 FAULT SYSTEM



(Buttinelli et al., 2020)

AREA3: FUCINO BASIN

NEW DATASET: THE 2008-2009 ARRAY FOR SITE EFFECTS



18 stations in continuous mode
Sampling: 125 Hz
Sensors: 5 s

Periods of operations

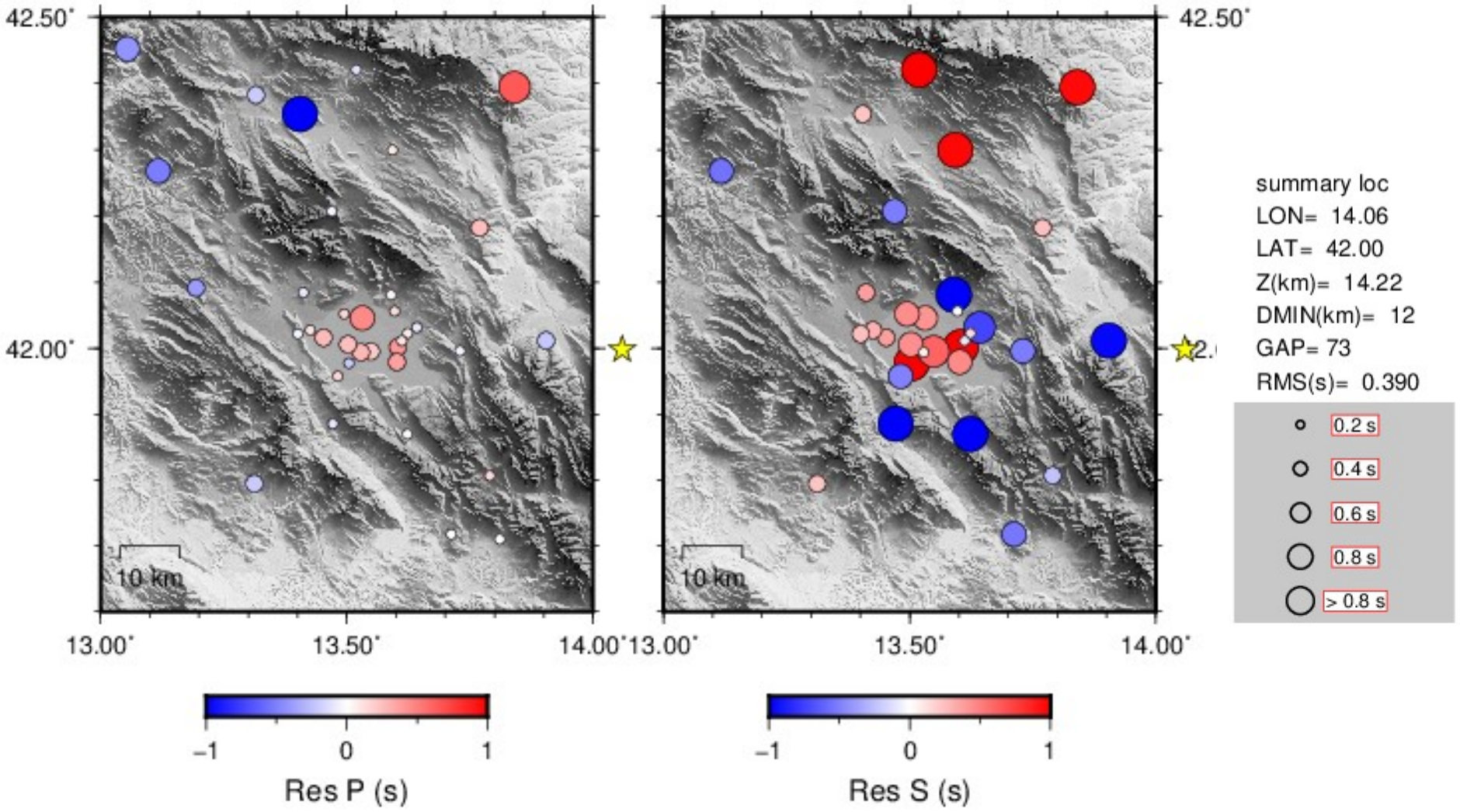
2008 OCT – 2009 JUL = 18 stations

2009 JUL – 2009 AUG = 17 stations

Cara et al., 2011

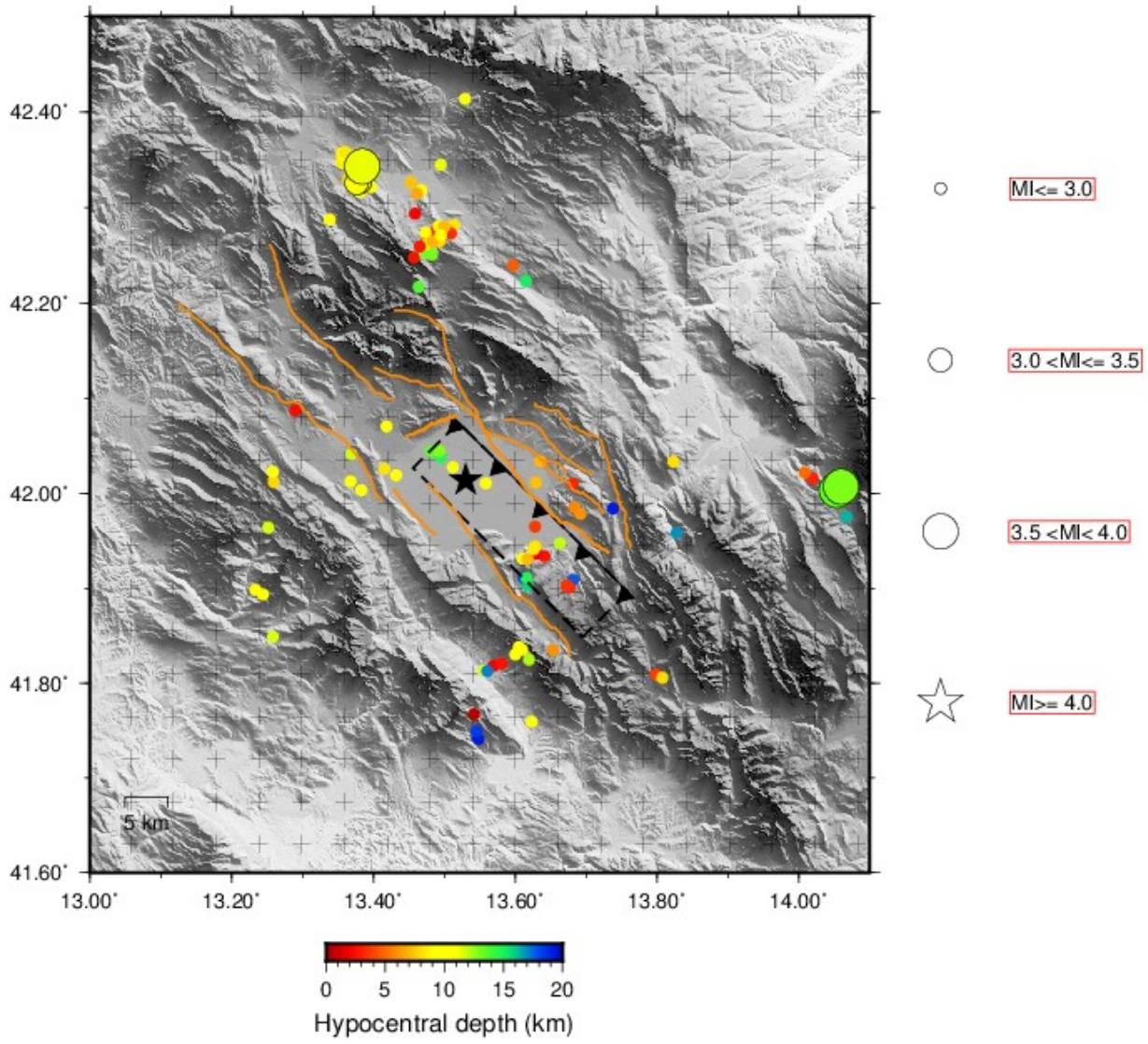
AREA3: FUCINO BASIN

Mw 3.6 CANSANO (Aq) RECORDED BY THE FUCINO ARRAY



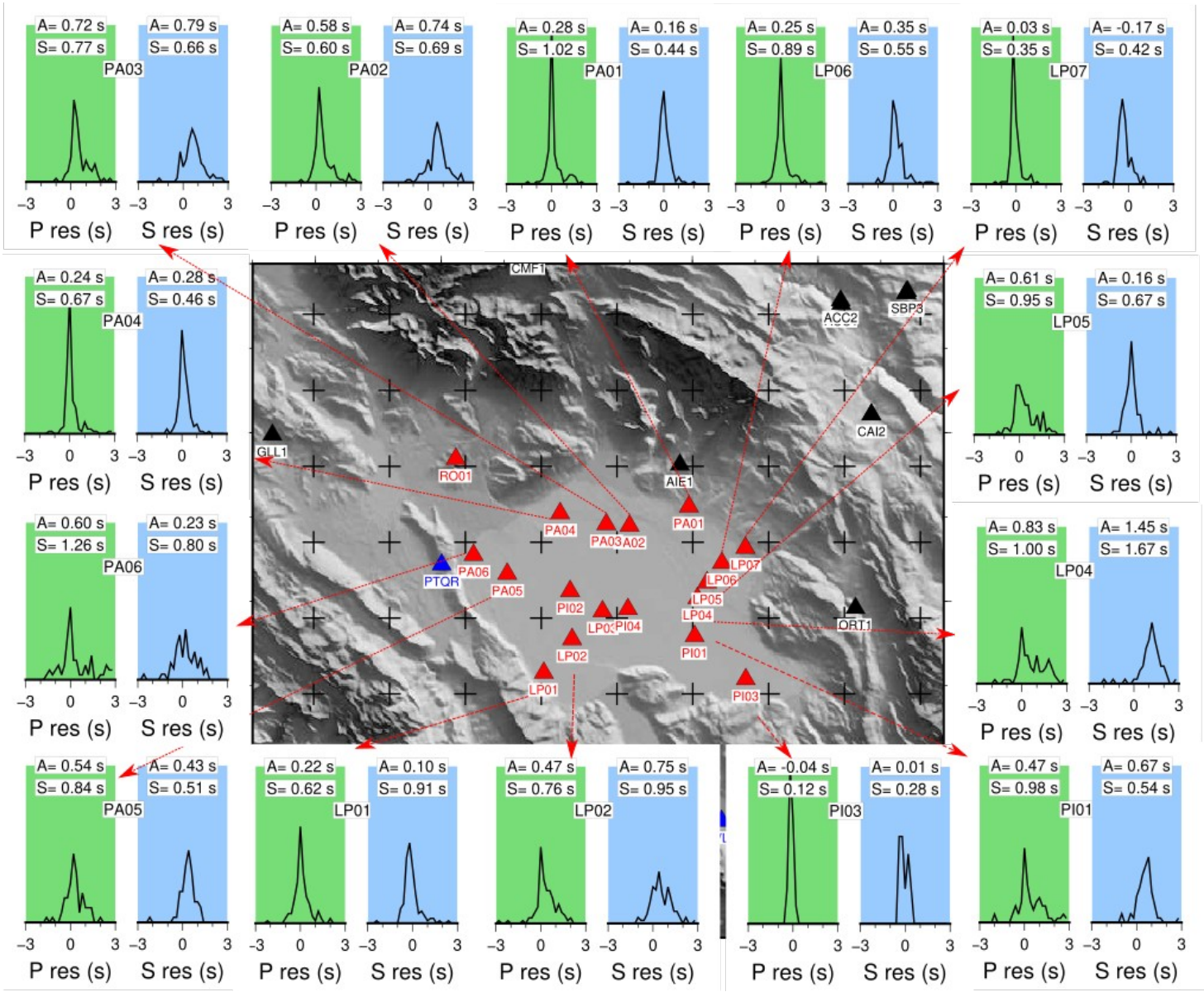
AREA3: FUCINO BASIN

NEW DATASET: 132 events from 2008-oct to 2009-apr



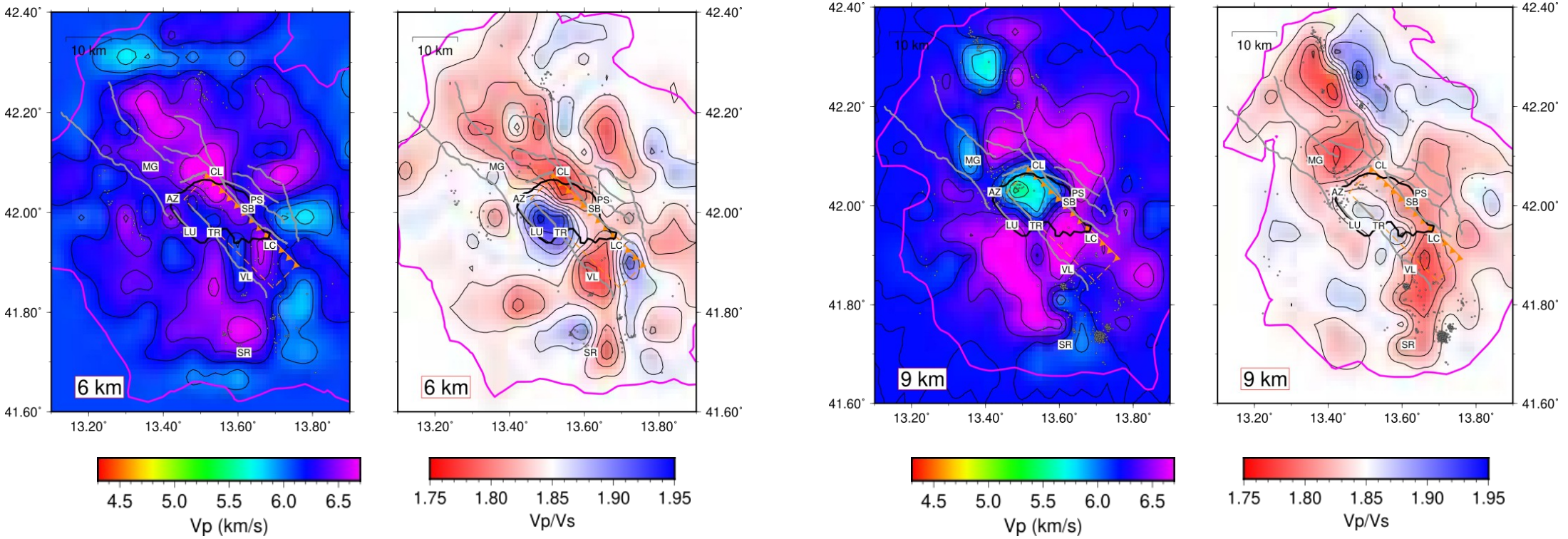
AREA3: FUCINO BASIN

RESIDUALS FROM 1D LOCATIONS



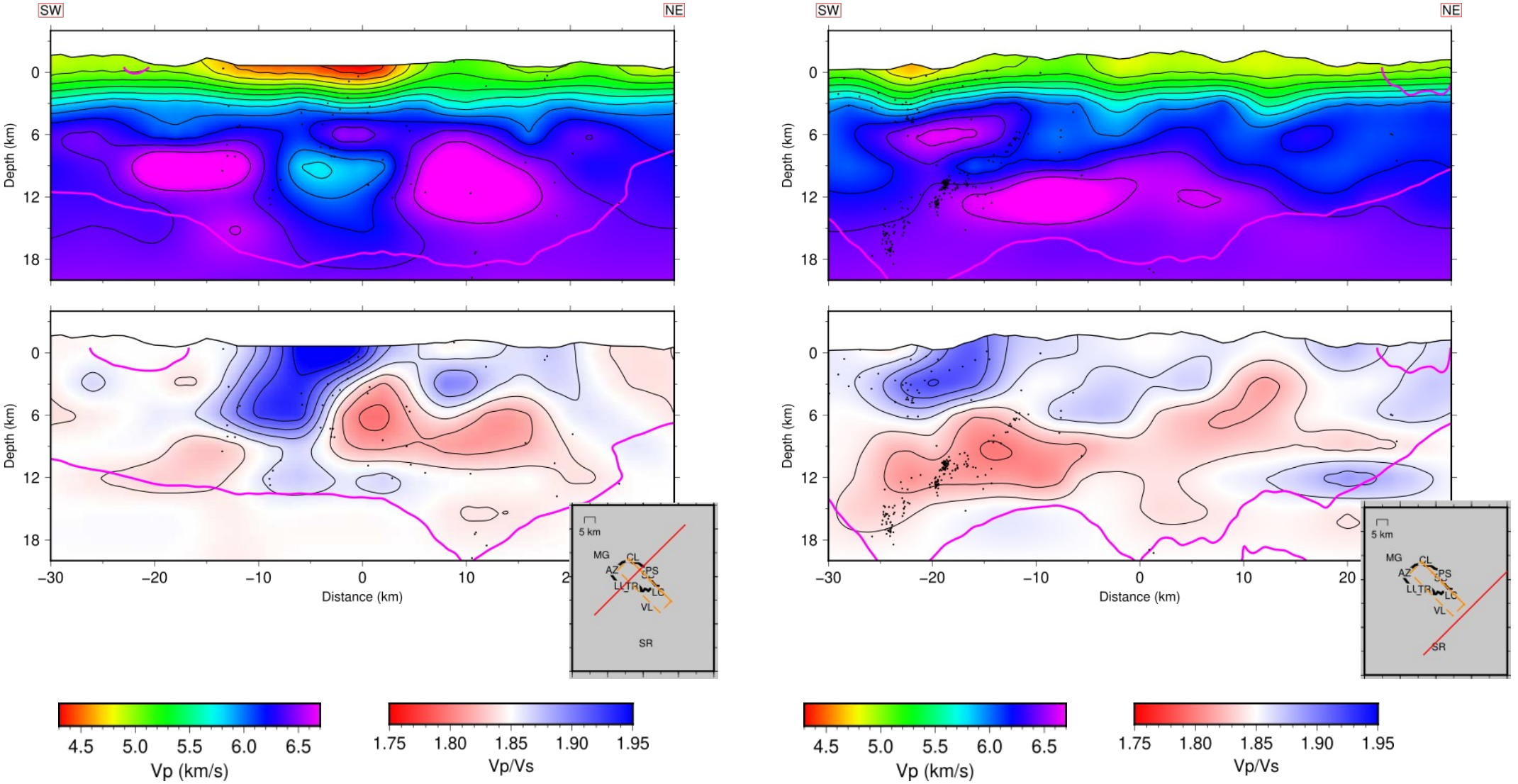
AREA3: FUCINO BASIN

PRELIMINARY 3D INVERSION



AREA3: FUCINO BASIN

PRELIMINARY 3D INVERSION



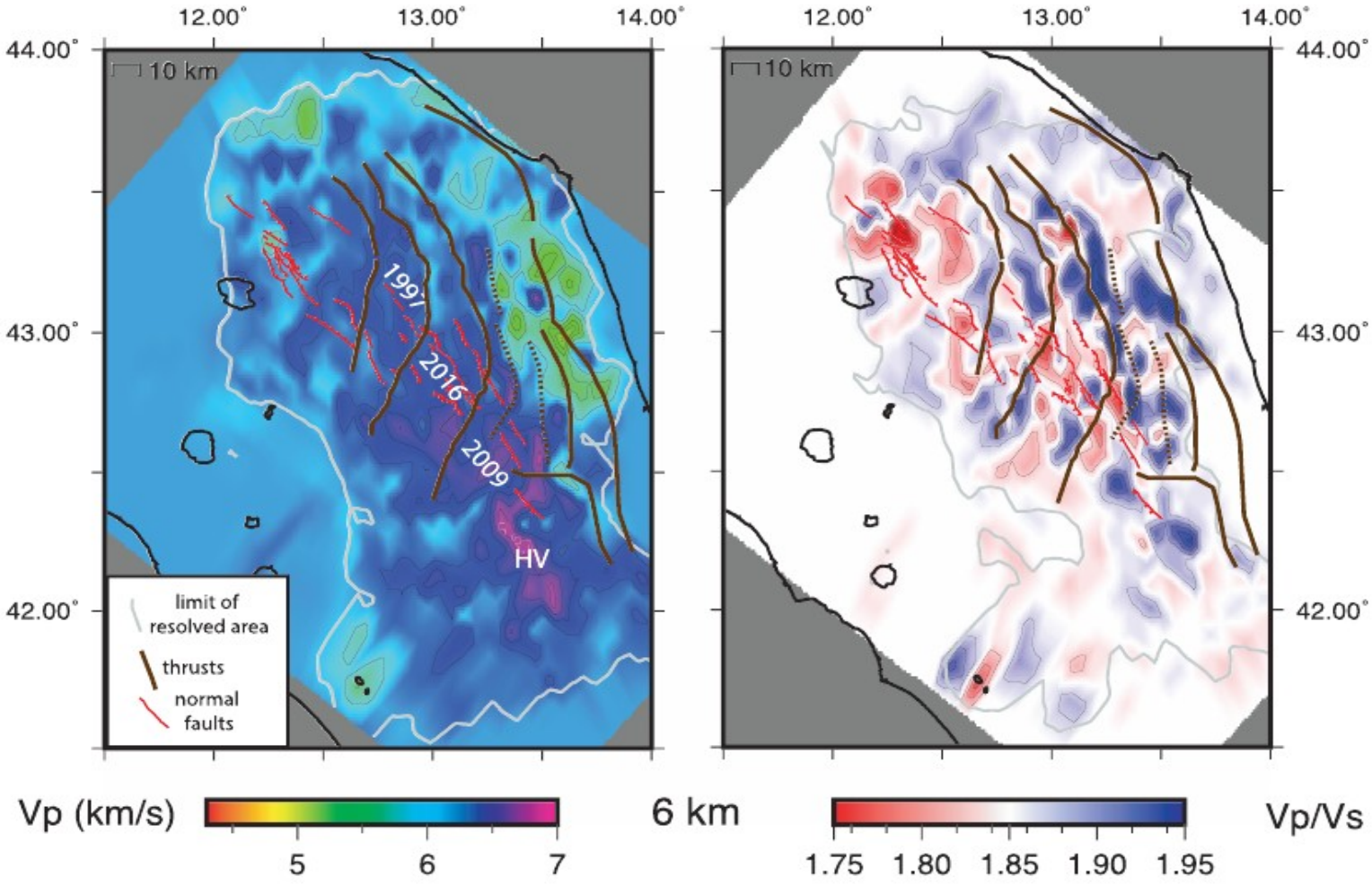
NEXT STEPS

AREA1: definition of a new “p-file” for new simulations of ground motion and comparison of the results with respect to Pitarka et al., 2021.

AREA2: creation of P and S arrival time dataset based on ML approach and tomographic inversion for a new Vp and Vp/Vs model.

AREA3: the new catalog of P and S arrival time at the Fucino array will be completed. A tomographic inversion for a Vp and Vp/Vs model will be carried out.

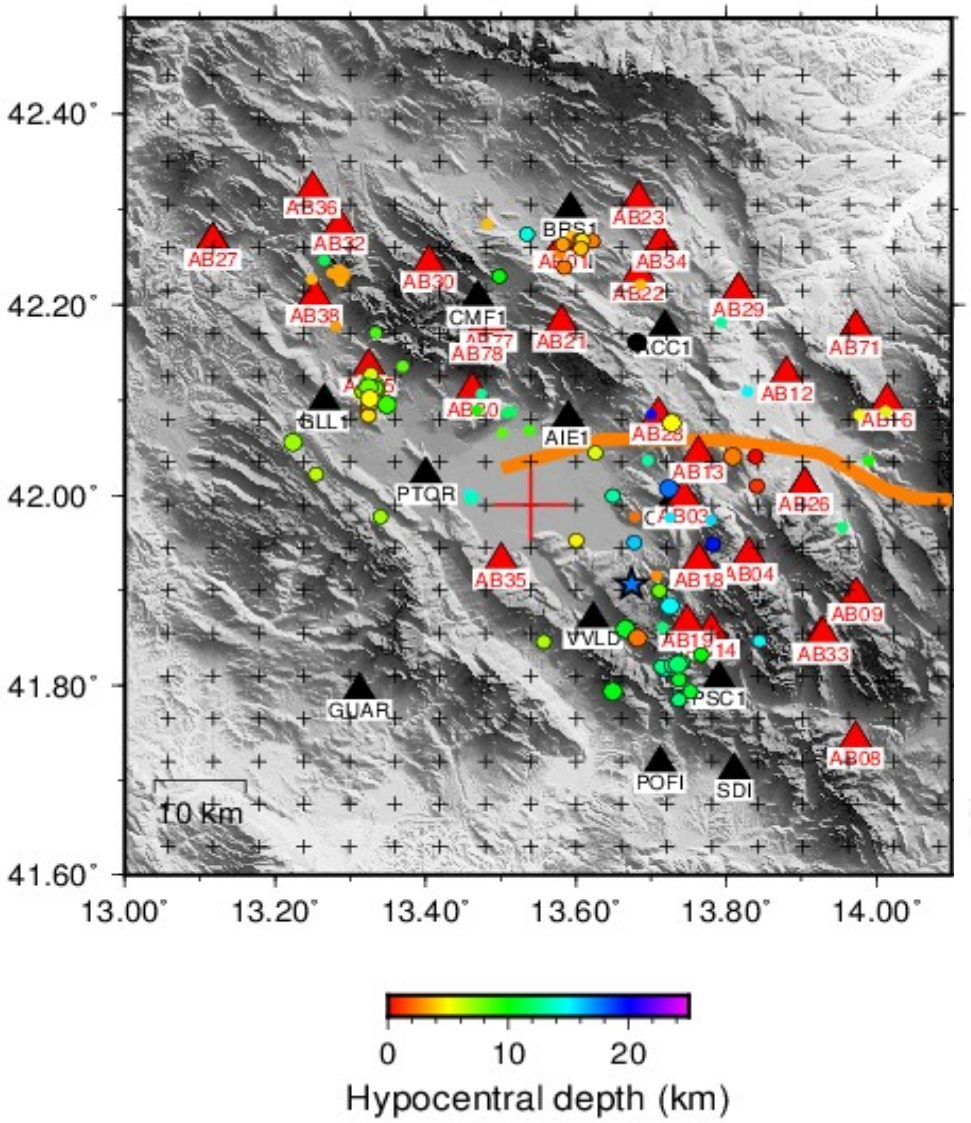
AREA1+AREA2+AREA3: LARGE SCALE MODEL



(Chiarabba et al., 2020)

AREA3: FUCINO BASIN

OLD DATASET: FIRB 2003-2004



LET of Abruzzo Apennines
10 x 10 x 5 km
(Chiarabba et al, 2010)