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INVESTING IN OUR FUTURE

PROGETTO OTRIONS

A first look at the Gargano (Southern Italy) seismicity as seen by the local scale OTRIONS seismic network

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ABSTRACT

On April 2013, a local scale seismic network, named OTRIONS, composed of twelve short period (1 Hz) three component seismometers, has been located in the northern part of the Apulia (Southern Italy). At each station, the acquisition system allows the recording of data in situ and their real time transfer to a seismic laboratory located at the Dipartimento di Scienze della Terra e Geoambientali of Università di Bari "Aldo Moro". The preliminary real time detection and localization of the events is automatically realized by using the SeisComp3 software. In the first two months of data acquisition, the network recorded about one hundred low magnitude (ML<2) earthquakes. In that follows, we present the results of a study aimed at investigating the crustal structure of the Gargano promontory. To this aim we analyzed the seismic events recorded in the area by the "Istituto Nazionale di Geofisica e Vulcanologia" (INGV) in the period 2006-2012 and the seismic events recorded by the OTRIONS network in the first two months of acquisition (march and april 2013). From the inversion of P and S travel times of INGV events we inferred a preliminary 3-layer Vp velocity model. The Moho is located at a depth of 27-30 km, in agreement with previous studies. A linearized inversion scheme that uses Velest (Kissling et al., 1994), allowed us to infer a 1D velocity model from the joint inversion of INGV and OTRIONS datasets of P and S travel times. On the whole, the number of earthquakes recorded by the OTRIONS seismic network is higher than 1200 in the period april,2013-march,2014.

INTRODUCTION

Despite the Gargano promontory is a part of the Adria foreland it is characterized by an unusual seismicity rate.

Historical documentation reports cases of catastrophic events which killed people in the order of thousands. Historical catalogues report at least eleven events having an estimated Mw>5.5 in the last millennium (Gruppo di Lavoro "Mappa della Pericolosità Sismica", 2004).

The present day seismicity seems to be related to tectonic activity along the approximately E-W trending Mattinata fault and adjacent faults (e.g. Del Gaudio et al., 2007). The Adriatic plate is formed by continental lithosphere and is subducting towards west below the Apennine chain; it represents a promontory formed by the collision of Africa and Eurasia plates. The Adriatic plate principally extends beneath the Adriatic sea, albeit it is exposed in Southern Italy in the Apulia region.

In the complex geodynamic context of the area, the Adriatic plate is considered as theforeland of both the Apennines and the Southern Alps, at west, and of both the Dinarides and Albanides thrust belts, at east (Figure 1).

Based on these evidences, in the frame of an European Territorial Cooperation Programme Greece-Italy 2007-2013 (acronym OTRIONS, INTEREG III), on April 2013 a seismic network was installed on the Gargano promontory (Figure 2). The experiment was aimed at improving the knowledge of the seismogenic potential of the area, through both the geometrical and dynamical characterization of the active faults and the assessment of elastic and inelastic properties of the crustal rocks.

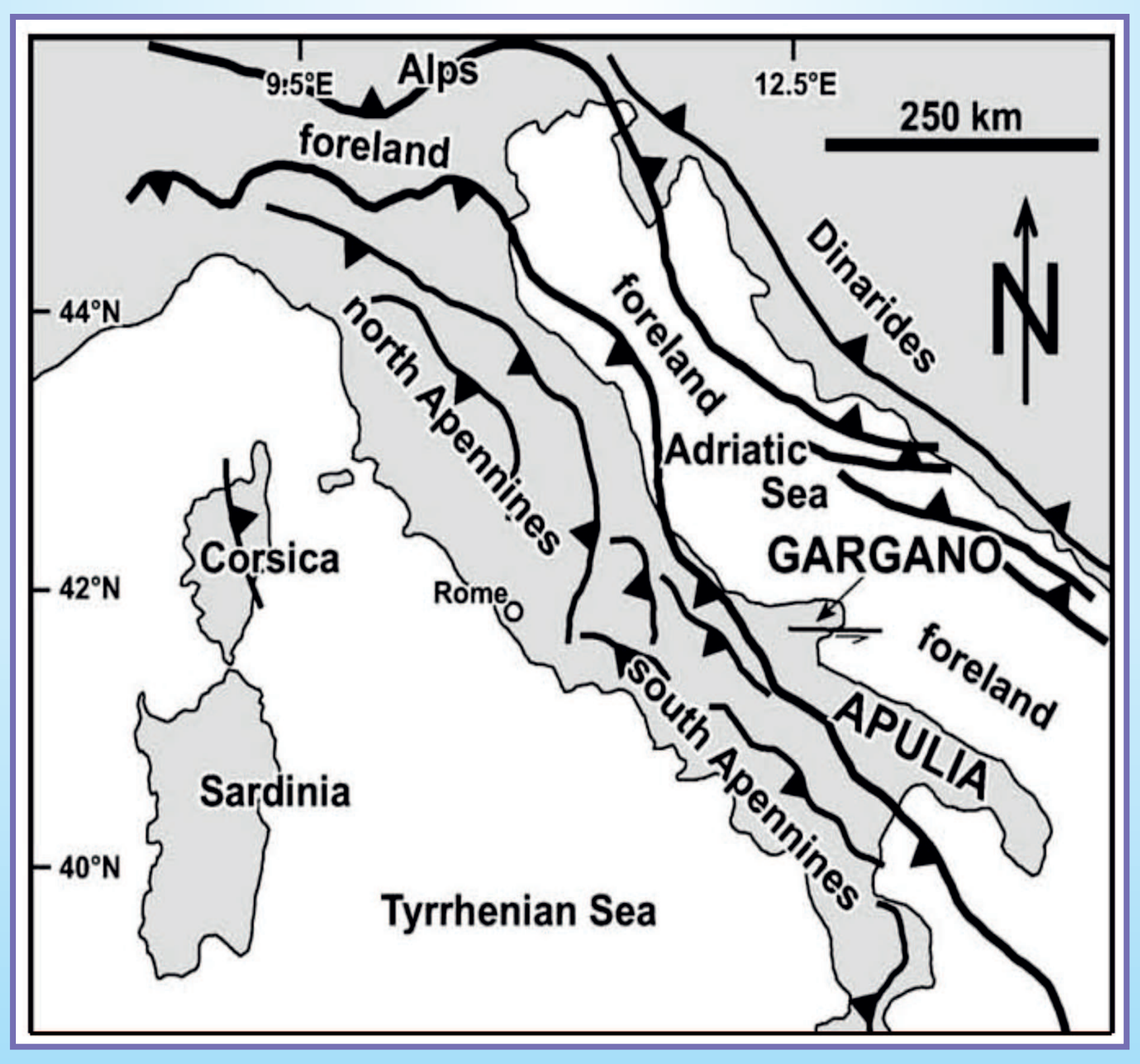


Figure 1. Geodynamics of Italy and surrounding regions. The major thrust fronts are represented.

THE OTRIONS SEISMIC NETWORK

On 24-April-2013 the OTRIONS Seismic Network was installed on the Gargano promontory.

The OTRIONS network is composed of 12 three component seismic stations whose position is shown in Figure 2.

Each station consists of a 24 bit SL06/SARA data-logger (dynamic range equal to 124dB at 100 sps) equipped with a short-period Lennartz 3D-V seismometer (flat response above 1 Hz).

The acquisition system allows the recording of data on an external USB device and their real time transmission, through a modem MOXA, to a seismic laboratory, located at the "Dipartimento di Scienze della Terra e Geoambientali of Università di Bari "Aldo Moro". The real time data transfer is realized by using a GPRS/UMTS connection. Data are transferred also to INGV and Regione Puglia centers. The transfer of data is managed by SEED-link protocol. A server collects data from the stations by using the software "OnCell Central Manager", that allows to archive data in SEED format. Moreover, these data are sent to a PC where they are managed by the SeisComp3 software .

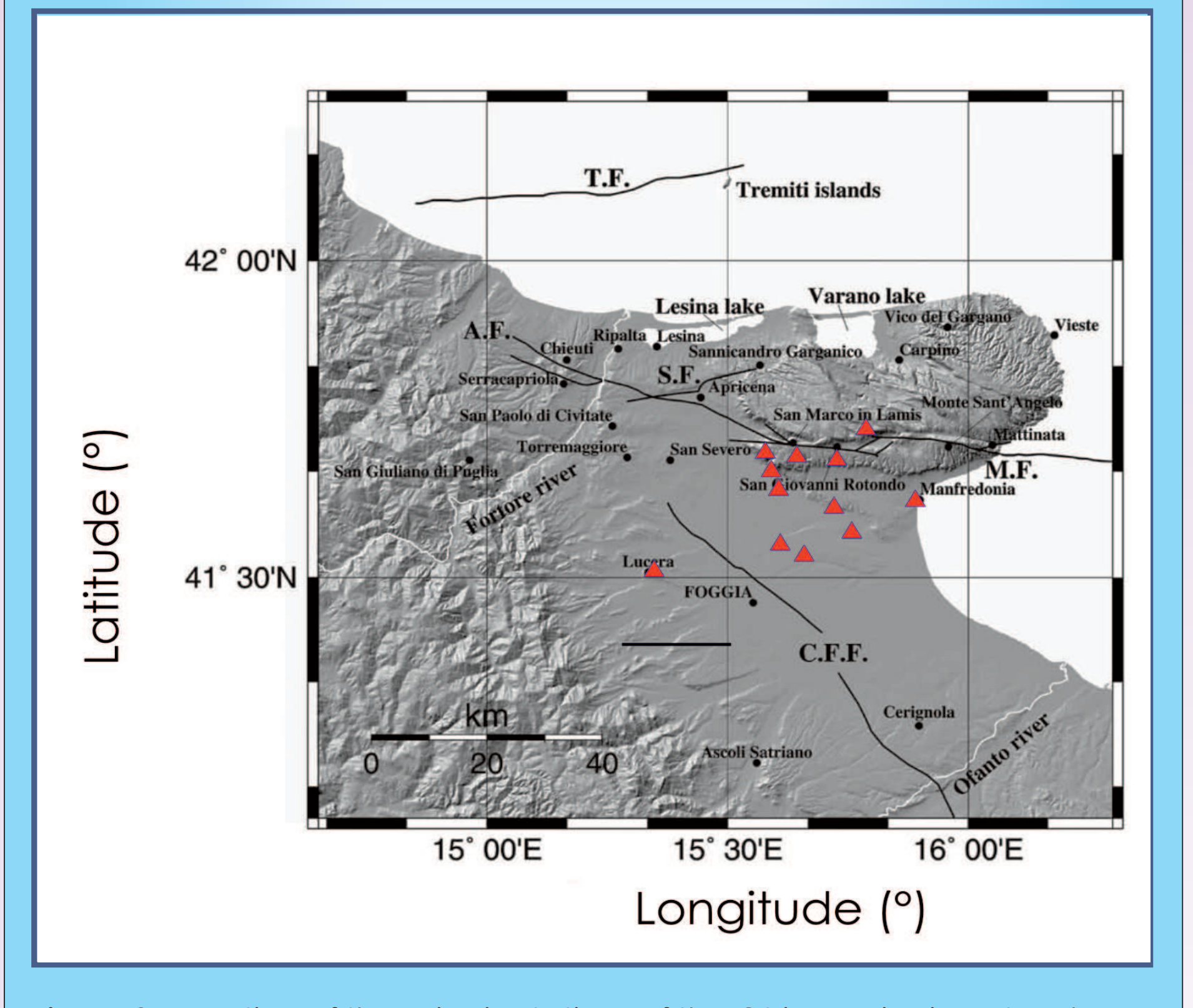


Figure 2. Location of the seismic stations of the Otrions seismic network. A.F: Apricena fault; M.F: Mattinata fault; T.F:Tremiti fault; C.F.F: Cerignola-Foggia fault; S.F: Sannicandro Garganico-Apricena fault (redrawn from Del Gaudio et al., 2007).

DATA SELECTION AND Vp/Vs RATIO

Following Matrullo et al. (2013), a first selection of data was performed by removing from the dataset all P and S travel times having a residual higher than a fixed threshold (1.5 s in this study) after their localization with a simple homogeneous velocity model (Vp = 5.5 km/s and Vp/Vs =1.8), maintaining in the dataset only those events that have at least four P travel times and 2 S travel times. Based on this selection rule, the total number of events is equal to 280 (200 recorded by INGV, as shown in figure (3) and 80 recorded by OTRIONS). After the removal of outliers, a total number of 3580 P wave travel times and 1800 S wave travel times was selected.

The overall dataset of P and S waves of the seismic events recorded by both the INGV and the OTRIONS networks was used to compute the Vp /Vs ratio. To this aim, we used the method proposed by Chatelain (1978), that consists of determining the slope of the straight line that best fits the difference between couples of S wave travel times $t_{si} - t_{sj}$ vs the difference between couples of P wave travel times $t_{pi} - t_{pj}$, for each couple (i,j) of stations and for each event. Data are plotted in Figure 4 and are well interpolated by a straight line with Vp/Vs=1.82, with a linear correlation coefficient R_2=0.98.

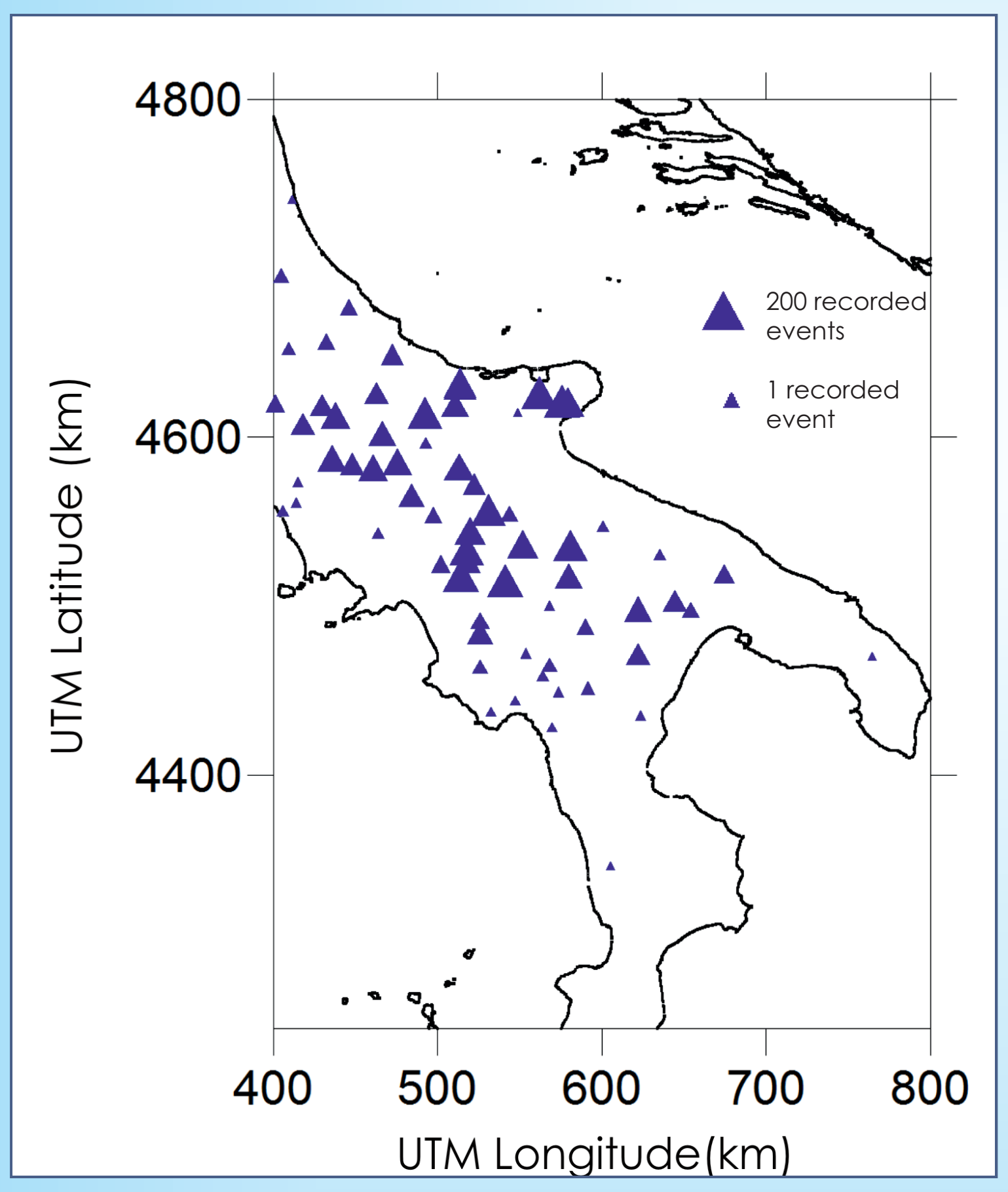


Figure 3 Location of INGV seismic stations considered in this study. The size of triangles is proportional to number of TP and TS readings at each station.

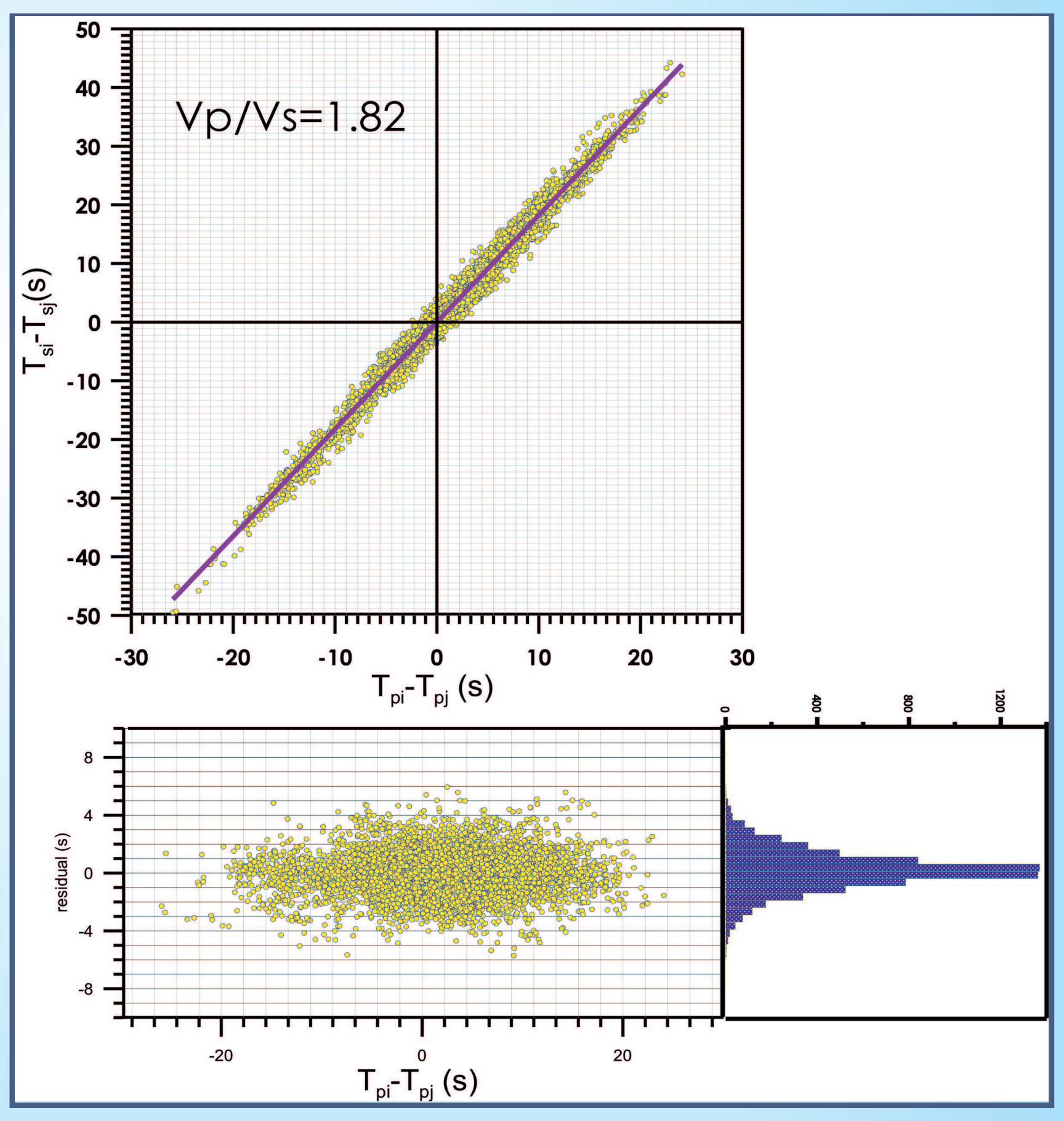


Figure 4. Modified Wadati diagram(Chatelain,1978) (on the top) and residuals on S wave travel times (on the bottom) .

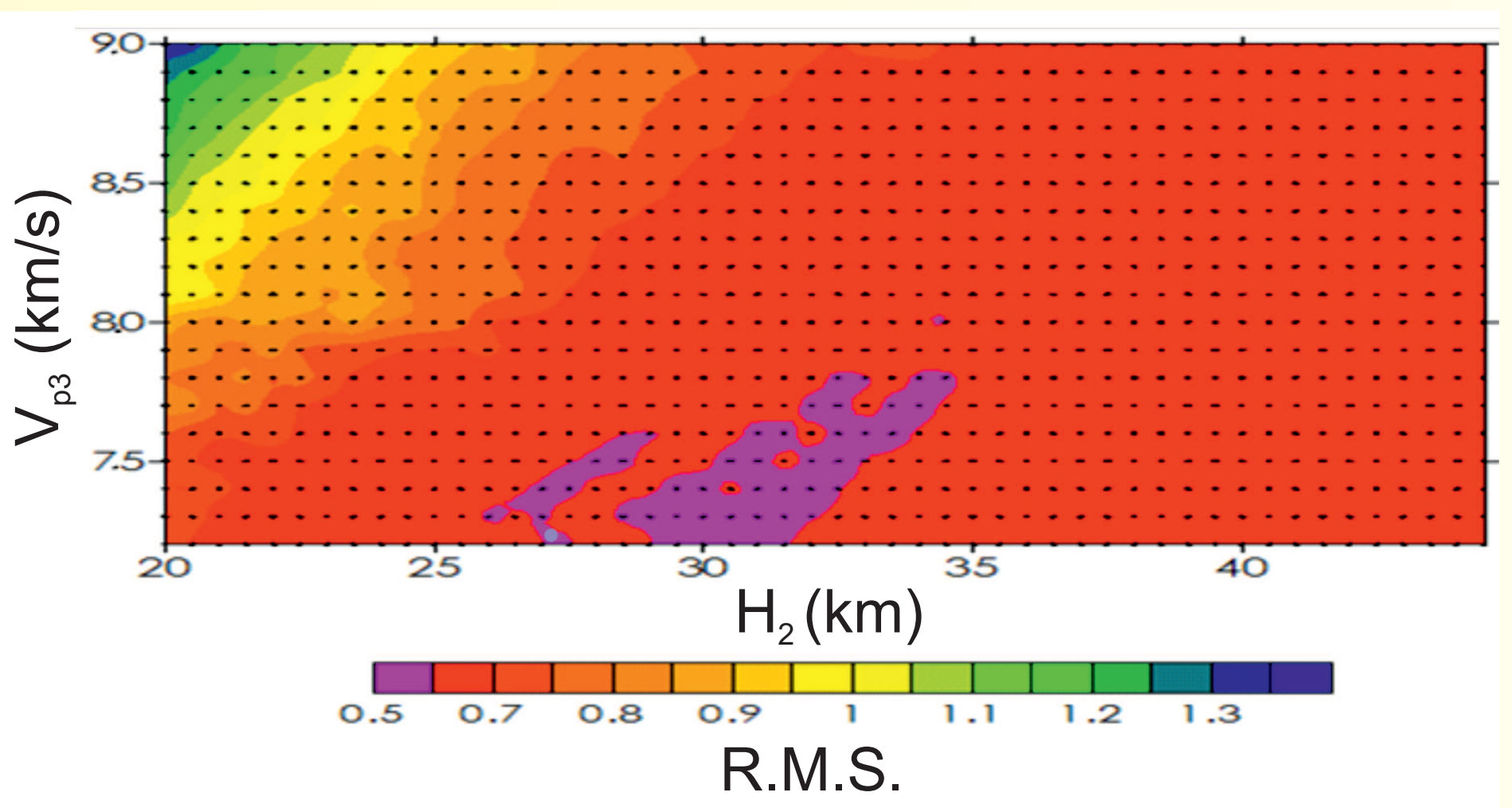


Figure 5. RMS plot in five-dimensional (V_{p1},V_{p2},V_{p3}, H_1, H_2) parameter space:in particular,V_{p3} vs H_2 is shown. Each point corresponds to an autput of HYPO71, related to the initial parameters: a fixed Vp/Vs ratio to 1.8, a tryal depth ranging from 20 km to 45 km and a tryal Vp ranging from 7 km/s to 9 km/s.

LAYERED Vp VELOCITY MODELS

A preliminary layered Vp and Vp/Vs velocity model for the area was calibrated by using the travel times of P and S phases of 220 seismic events localized in the Gargano region by INGV in the period 2006-2012.

Figure 3 shows the position of the INGV seismic stations that recorded at least one event.

In our analysis we used a multi-scale approach that consists of progressively increasing the degree of complexity of the crust. First, we inferred the best fit half-space model; successively we computed the best fit two layer Vp model and, finally, the best fit three-layer *Vp* model.

The procedure is based on a grid-search method with different degrees of complexity that depend on the number of layers used in each analysis. The number N+1 of unknown model parameters depend on the number N of considered layers. The model parameters are the Vp velocity of each layer and their thickness (figure 5).

The technique required the calculation of many thousand forward models and their comparison with data.

In each point of this N+1 dimension parameter space, the origin time and the spatial coordinates of all the events were computed, using HYPO71 and the total RMS was used to evaluate the matching of model to data. The procedure was stopped when no further variance reduction was obtained.

The minimum RMS is equal to 0.55 s. A variance reduction with respect to the homogeneous model of about 15% and a RMS reduction of 9% was inferred. The three obtained models are shown in figure 6 and summarized in table I.

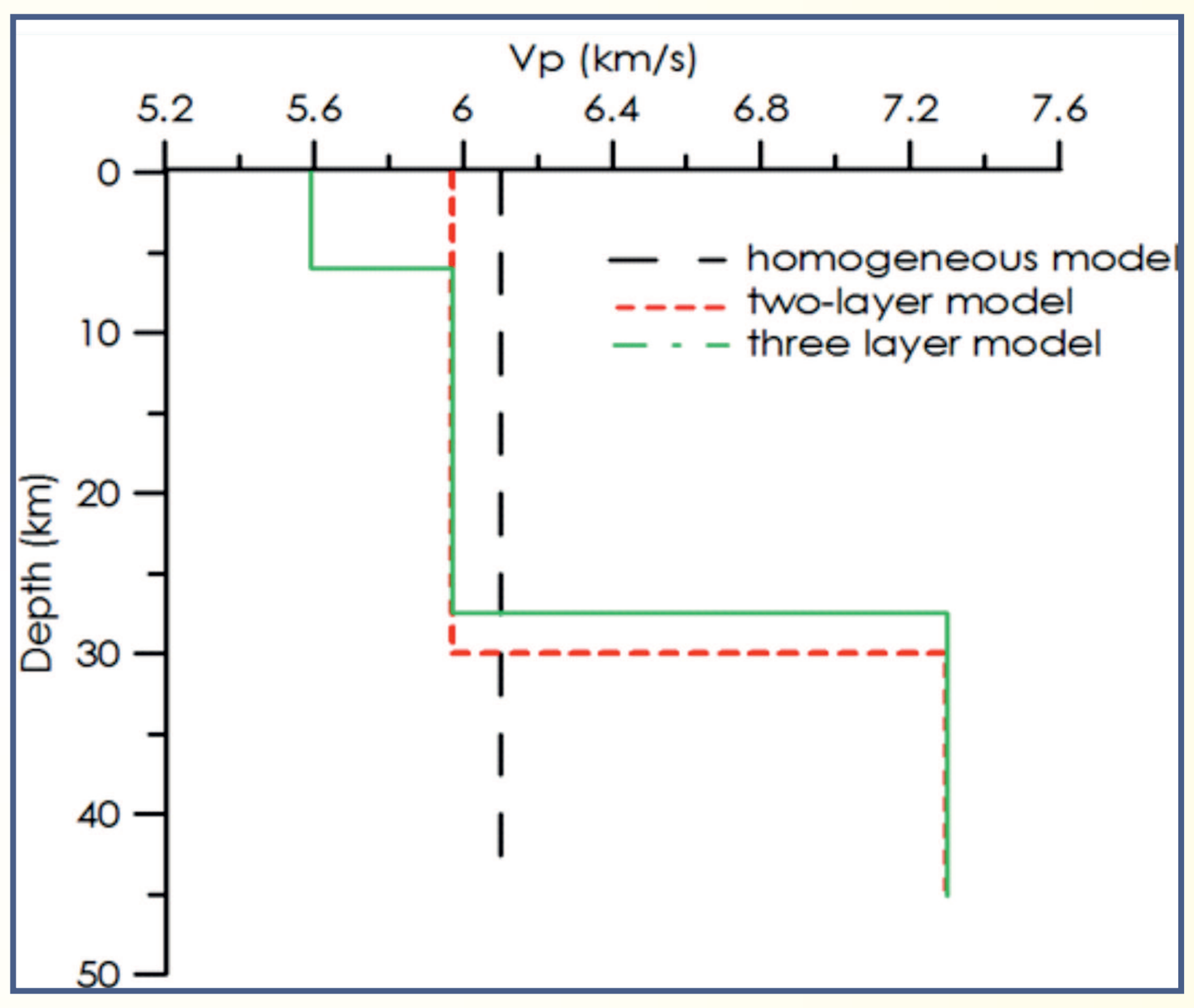


Figure 6. The layered Vp velocity models obtained withthe grid-search method.

	Vp (km/s)	H (km)	R.M.S. (s)
Homogeneous Model	6.1	----	0.69
2 Layer Model	V_{p1} = 5.9 V_{p2} = 7.3	H_1 = 30	0.61
3 Layer Model	V_{p1} = 5.6 V_{p2} = 6.0 V_{p3} = 7.3	H_1 = 5 H_2 = 27	0.55

Table I. Inversion results for the layered models

http://www.otrions.uniba.it

THE 1D VELOCITY MODEL

We used the Velest code (e.g. Kissling et al. 1994) to determine a "minimum" 1D velocity model. This code is based on a damped least square approach and several iterative inversion steps and allows to infer the model parameters through a linearized approach. As an effect of linearization, the inferred parameters (seismic velocities and hypocenter locations) are generally dependent on the starting values.

As concerns the actual dataset of P and S travel times, the main problems are represented by both the relatively small number of available events (320) and the greater source to receiver distance range of the events recorded by INGV network, that has a typical length scale (in the order of hundred km) greater than the local scale (in the order of ten km) of the OTRIONS network (figure 2). For this reason, we decided to reduce the number of degrees of freedom by fixing the Vp/Vs value and, therefore, the 1D Vs profile. For the same reason, we did not consider the effect of the station delays, even because the number of INGV stations that recorded at least one event is higher than 100. As concern the inversion of Vp velocity profile, the final minimum 1D model was obtained as the average of several inverted 1D models, arising from different starting velocity models, chosen to account for the present day knowledge of the crust in the area. As starting velocity model, we considered the nine velocity models shown in figure 7a.

Both the two homogeneous velocity models and the three gradient velocity models were chosen on the basis of the available values of the seismic velocities of the upper crust in the Gargano promontory, by taking into account the well known heterogeneity of the crust at a local scale in the area.

In each inversion process (i.e. for each starting velocity model) we followed the guidelines prescribed by Kissling et al. (1994), by using different damping coefficients for hypocenter parameters and velocity model. We do not allowed the presence of low velocity layers in the inversion. In fact, after several preliminary trial runs, we observed that the use of low velocity layers gives rise to unstable solutions, as often described in literature (e.g. Kissling, 1994, Matrullo et al.,2013).

The nine inferred velocity model arising from the inversion process are summarized in figure 7b. With the exception of the velocity model of Costa et al. (1993), which gave rise to a higher final RMS (0.43 s), the adherence of model to data is comparable for the remaining eight velocity models (RMS of the order of 0.38 s, as shown in figure 8). Therefore the averaged 1D velocity model was computed using only these eight models (figure 7c).

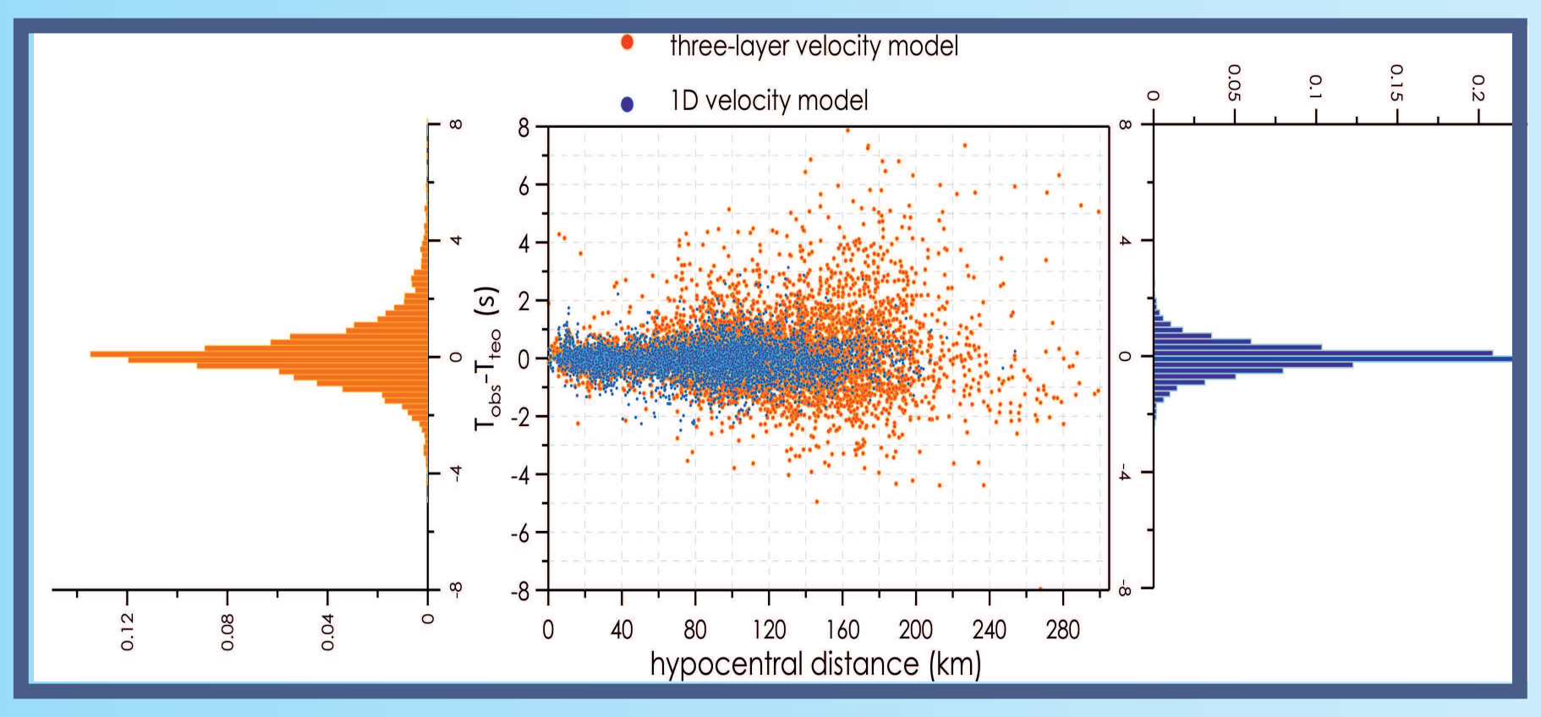


Figure 8 .Plot of residuals between observed and theoretical travel times, and their histograms. Orange points refer to the three-layer velocity model; blue points refer to the minimum 1D velocity model.

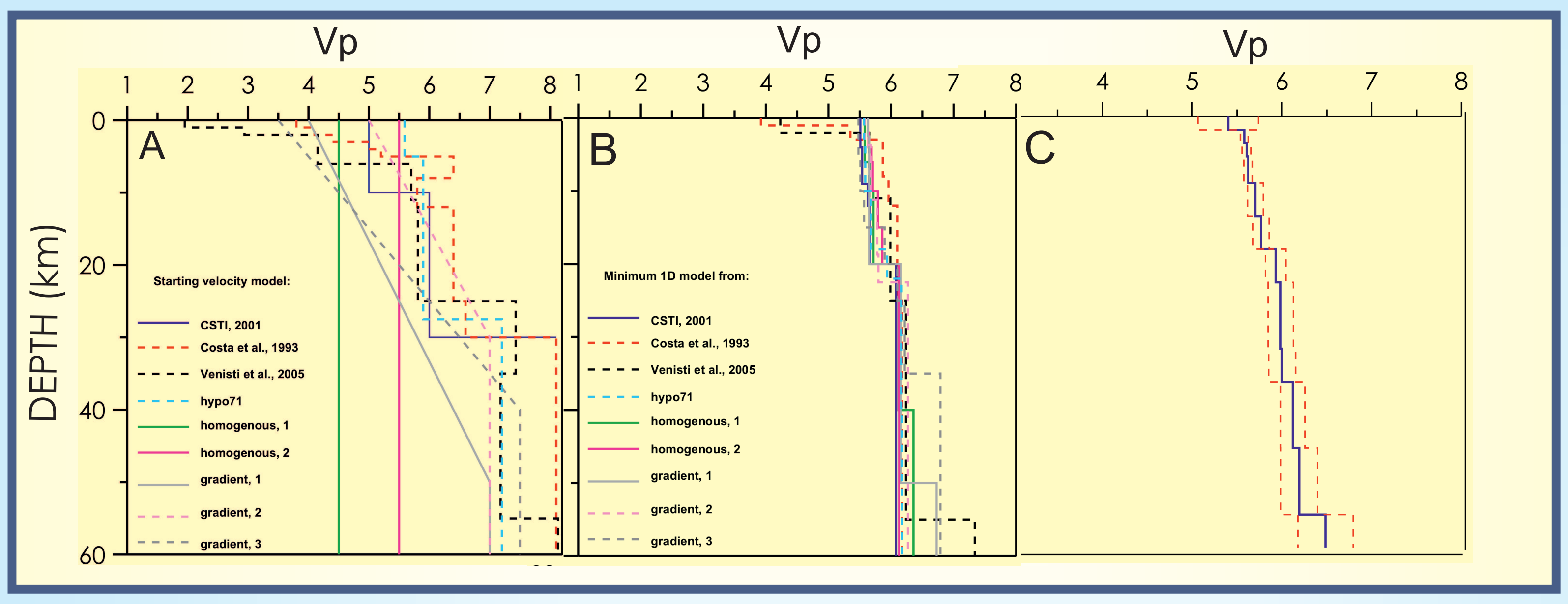
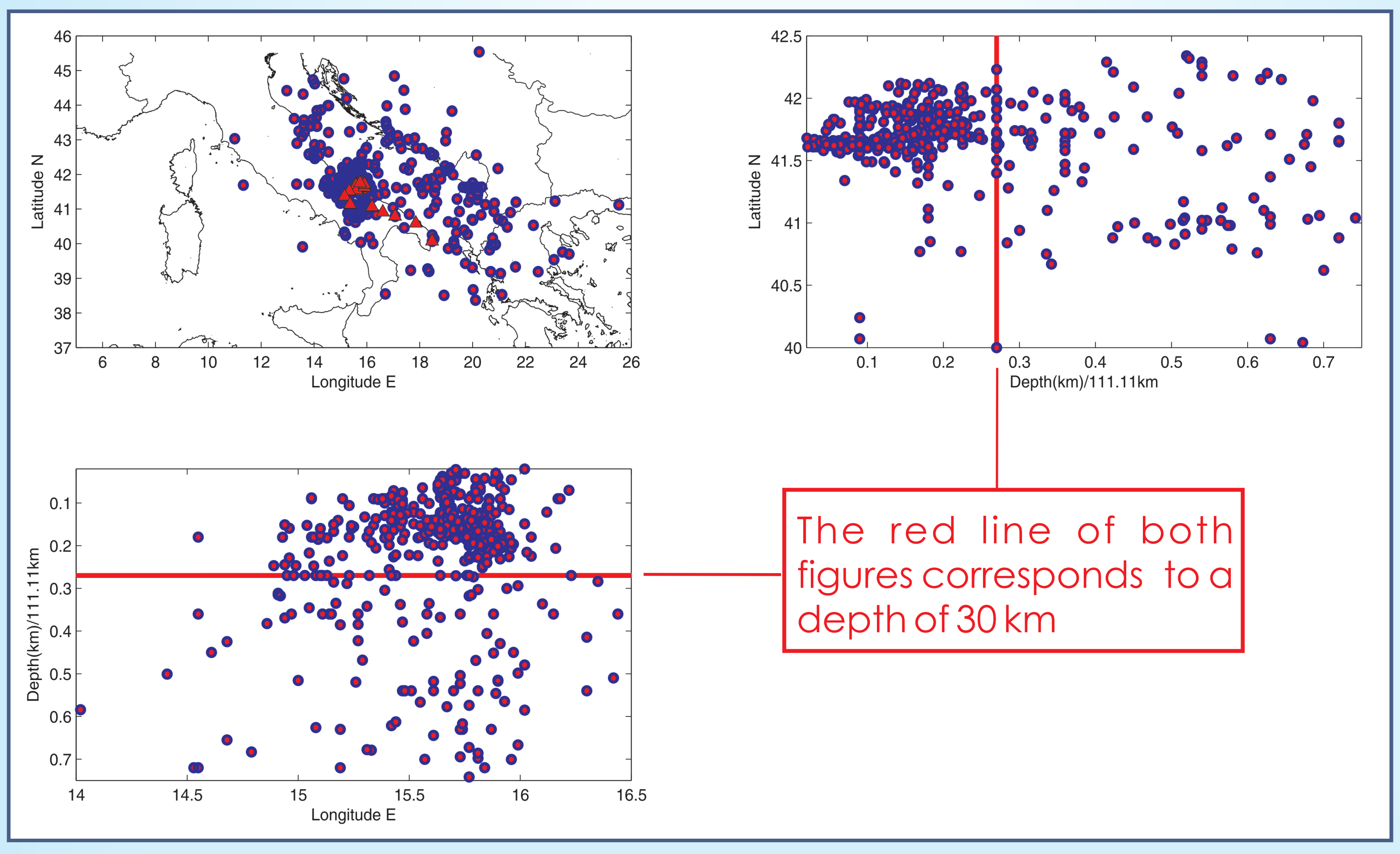


Figure 7. a) The nine starting Vp velocity models used in the linearized inversions; b)The nine inverted 1D velocity models; c) the minimum (blue line) 1D velocity model.Red lines represent the error bounds.



The red line of both figures corresponds to a depth of 30 km

Figure 9. On the left top panel: the geographic positions of the seismic events recorded by the OTRIONS seismic network in the period that ranges from April 2013 to March 2014; on the right top panel, the latitude vs. the normalized depth (depth/111.11km) of the seismic events; in the bottom panel, the longitude vs. the normalized depth of the seismic events.

DISCUSSION AND CONCLUSION

The dataset of all events occurred between April-,2013 and March,2014 have been relocated using the average minimum 1D model (figure 9). The most part of the events occurs in the Gargano area. In this area, the events tend to cluster between S. Giovanni Rotondo, Monte S. Angelo and Manfredonia. Therefore, the position of the epicenters confirms that the seismic activity is mainly related to the tectonic activity in the shear zone that comprises the Mattinata Fault and the Apricena Fault and some minor lineaments, as found in previous studies.

The events tend to concentrate until to a depth of about 30 km (figure 9). Moreover, in the three-layer velocity model (figure 6) Vp abruptly increases to 7.3 km/s at a depth of about 27-30 km. These two results seem indicate that the Moho, in the area, is at a depth of about 27-30 km, as previously inferred in a teleseismic receiver function analysis (Piana Agostinetti and Amato, 2009).

Moreover, we note the similarity of Vp/Vs value inferred from the grid search technique (1.81) with the value inferred from the Chatelain (1978) method for the whole dataset (1.82) (figure 4). These values are in close agreement with the results obtained by Piana Agostinetti and Amato (2009) and may indicate that the crust, in the Gargano area, is characterized by a moderate fluid content. If we compare this value with the average Vp/Vs=1.89 (Chiarabba and Amato, 2003) of the near Umbria-Marche Apennine, we conclude that the Gargano promontory is characterized by a minor fluid content, that could be indicative of a minor degree of fracturing of the crust.

A significant variance reduction is obtained using the 1D model with respect to the previously inferred 3-layer model (30 % of RMS reduction) (figure 8). An average total residual of 0.36 s is inferred in the 1D model, that reduces to 0.24 s for the data recorded only by the OTRIONS network .

The small number of events considered in this study does not allow us to image the geometry of the active faults. This objective will require the further analysis of the about one thousand events further recorded by the OTRIONS network in the period from May- 2013 to March-2014. The analysis of these events is still in progress and could help us to better constrain the elastic properties of the crust in a future study.

As final consideration we note that the use of a local scale seismic network in a region of apparently moderate seismicity allows the detection of very small magnitude (minimum ML=0.3) events, that are extremely important to better extend the range of completeness of seismic catalogues and therefore in the evaluation of the seismic hazard of an area.

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