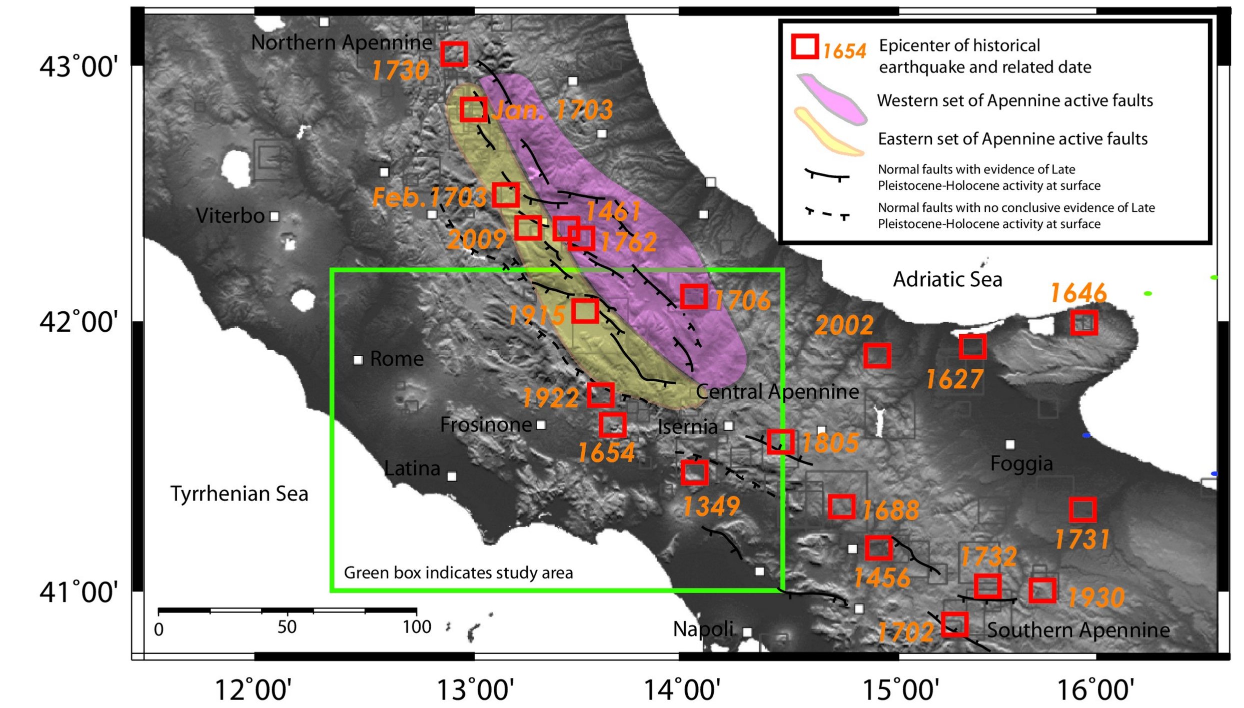
Poster session SM6.1/NH4.12/TS4.6
Abstract identification number:EGU2016-1592.

Science Against Barriers
Build Bridges not Walls

Seismicity and seismogenic structures of Central Apennines (Italy): constraints on the present-day stress field from focal mechanisms – The SLAM (Seismicity of Lazio-Abruzzo and Molise) project.

A. Frepoli, G.B. Cimini, P. De Gori, G. De Luca, A. Marchetti, S. Monna, C. Montuori, N.M. Pagliuca

Istituto Nazionale di Geofisica e Vulcanologia,via di Vigna Murata, 605 -00143 Rome, Italy



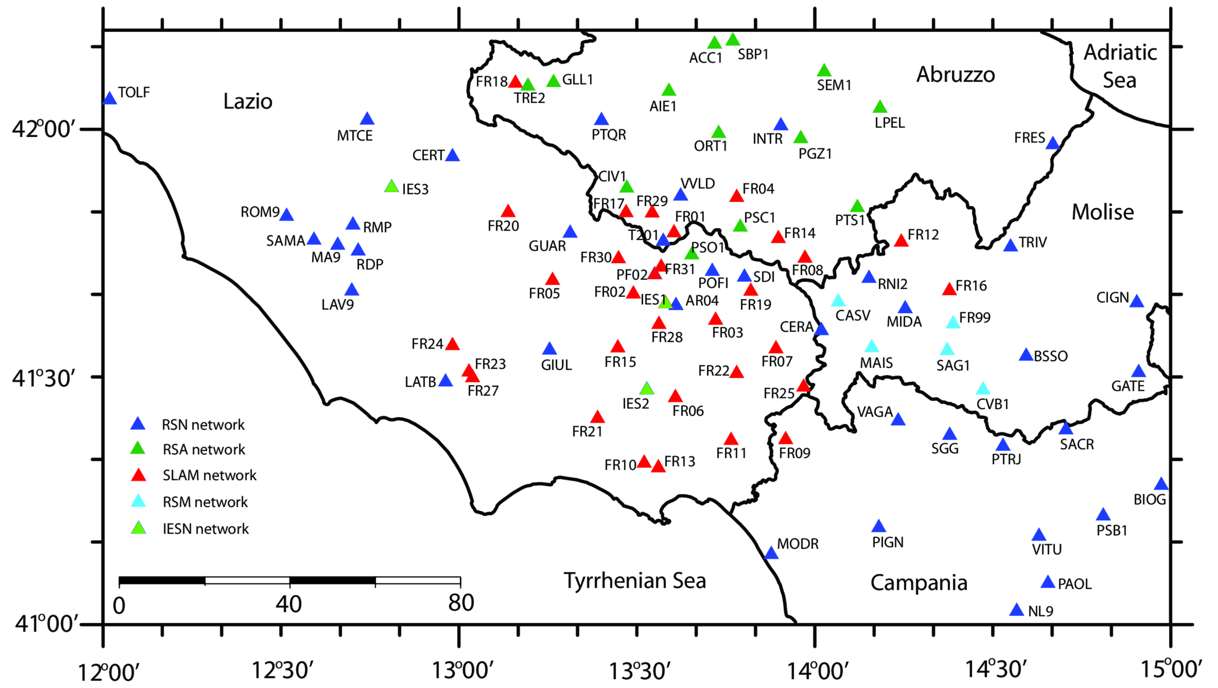
The aim of the **SLAM** (Seismicity of Lazio, Abruzzo and Molise region) project is to provide new insight on the seismotectonic and seismogenesis of a wide portion of central Italy situated between areas affected by recent destructive events such as the 2009, Mw = 6.3, L'Aquila earthquake to the north and the 2002, Mw = 5.8, Molise earthquake to the east. We present new results for the microseismic activity in the Central Apennines, occurred in the period 2009 – 2013, by analyzing seismogram recordings from two temporary networks of up to 17 stations in combination with data from three networks of permanent stations.

The study region has been historically affected by many strong earthquakes, some of them very destructive. The Central Apennine is characterized by several urban communities with more than 10,000 inhabitants that lie potentially close to active faults. For this reason this work can give an important contribution to the seismic hazard assessment in this area.

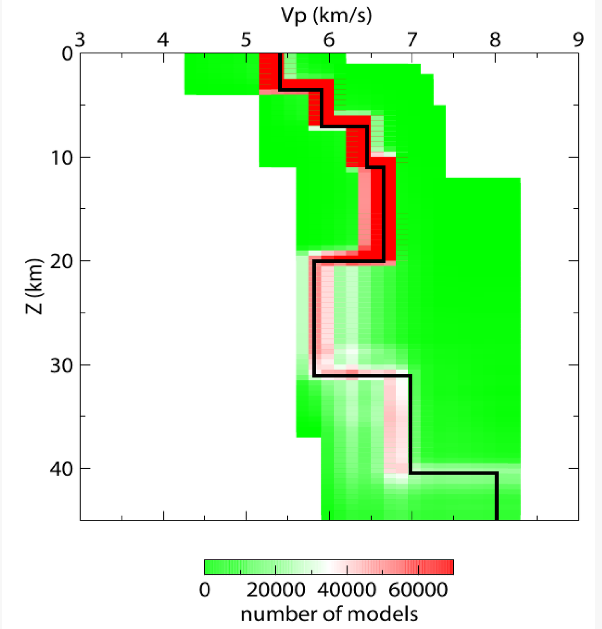
We use data from three permanent seismic networks: the Italian National Seismic Network (RSN) of the Istituto Nazionale di Geofisica e Vulcanologia (INGV) with 48 stations within the studied area, the Abruzzo Regional Seismic Network (RSA; De Luca *et al.*, 2009) with 28 stations and the Molise Regional Seismic Network (RSM) with 5 stations. In addition new digital data were available from two temporary arrays: the first one of up to 4 stations (pilot study), and the second one of up to 17 stations, in the period 2009-2013. In total this study is based on data from 98 stations. The 17 temporary stations were deployed in 31 different sites to improve detection of the small earthquakes in the seismic swarms.

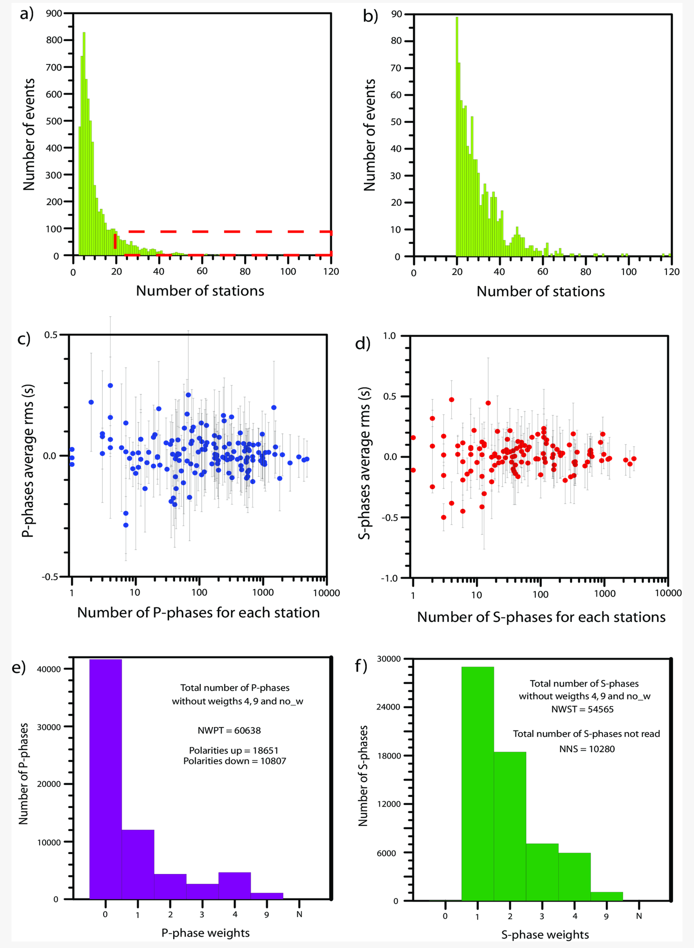
Technical information:
- 4 stations deployed in the Marsica-Sorano area (2009): 3-component Lennartz 1s sensor, high-dynamic (24 bit) Reftek RT130 digitizer in continuous mode, 100 sps,
- 17 stations of the SLAM project: 3-component Lennartz 5s sensor, high-dynamic Reftek digitizer in continuous mode, sampling rate of 125 sps.

Seismic networks



1D Velocity Model





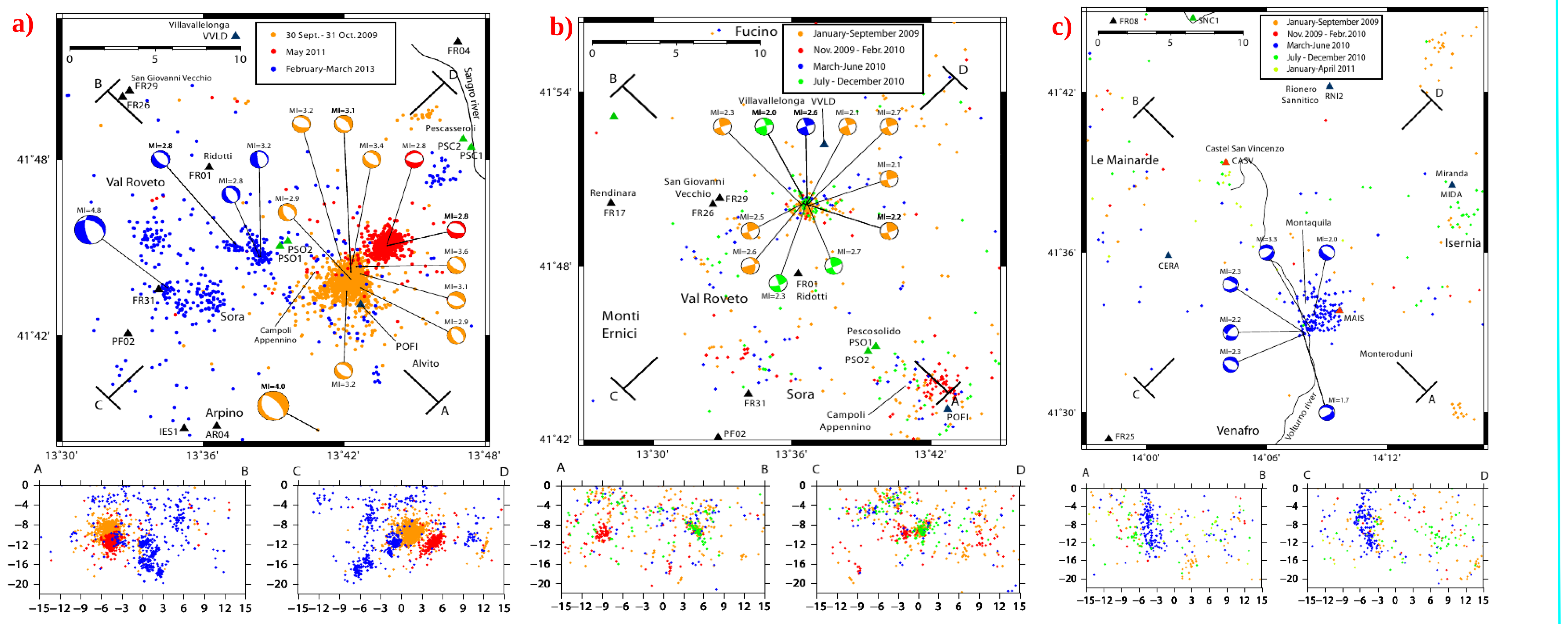
The reference 1D Vp velocity model has been computed by the application of a genetic algorithm (Holland 1975; Sambridge and Gallagher, 1993). We use a constant value of 1.84 for Vp/Vs defined by the Wadati method. The figure shows all the models resulting from the GA global search. The colors indicate the number of models. The red color expresses the velocity profiles more frequent while the black line is the selected velocity model.

- Between January 2009 and December 2013 we recorded 7011 earthquakes that occurred within the studied area.
- Local magnitudes M_L ranging from 0.4 to 4.8 (from the INGV catalog).
- Hypocentres were relocated by using a refined 1D crustal velocity model. The majority of the hypocenters are located beneath the axes of the Apenninic chain, while the seismic activity observed along the peri-Tyrrhenian margin is lower.
- Hypocentral depth distribution exhibits a pronounced peak of seismic energy release in the depth range between 8 and 18 km. Seismicity extends to a depth of 32 km.
- During the observation period we recorded two major seismic swarms and one seismic sequence in the Marsica-Sorano area in which we have had the largest detected magnitude (M_w = 4.8).

- In the upper crust (0-10 km depth) Vp ranges from 5.4 to 6 km/s reflecting the presence of carbonate rocks widely outcropping in central Apennines. In the mid-crust (10-20 km) the increase of Vp up to 6-6.7 km/s is consistent with dolomites and evaporites at the bottom of carbonate platforms. The deepest layers are poorly resolved since seismicity concentrate at shallower depths. However, below 20 km depth, the majority of the models show a marked decrease of Vp (5.8 km/s) that may be ascribed to metamorphic formation above the crystalline basement.

Swarm activities during the observed time period

a) Two main swarms are located in the area of Campoli Appennino (Marsica-Sorano area, October 2009 and May 2011, respectively) and the largest sequence detected (mainshock M_w = 4.8, February 16, 2013) was localized close to the city of Sora. In the Marsica-Sorano area is concentrated approximately the 54% of the whole examined seismicity occurred in the studied period.
- The first Campoli Appennino seismic swarm started on September 30, 2009, with a M_L 3.2 event, and was characterized by 1309 events lasted in a period of one month, with activity peaks in the day 30 September, then from 6 to 10 October and from 14 to 16 October. The maximum local magnitude was M_L = 3.6 and only 7 earthquakes have had magnitude equal or larger than 3.0. The first Campoli Appennino swarm was preceded by an earthquake of M_L = 4.0 on August 6, 2009, without aftershocks at 13.5 km of hypocentral depth, located between Arpino and Casalvieri, approximately 10 km to the south of the October 2009 swarm.
- The second Campoli Appennino swarm lasted during May 2011 with 739 events and a maximum local magnitude M_L of 2.8. This second swarm is slightly shifted to the north-east with respect to the October 2009 one. Both swarms are showing a south-west dipping plane (~ 70°) with hypocentral depths ranging from 7 to 13 km.
The Sora sequence started with the main shock (M_L 4.8) on February 16, 2013, and lasted until the end of March with ~ 300 aftershocks. Hypocentral distribution of this sequence shows two clusters. The deeper one, in which is located the main shock hypocentre at 18.6 km of depth, is characterized by hypocentral depths ranging from 12 to 18.6 km, while the shallower cluster displayed hypocentre between 5 to 14 km of depth. The shallower cluster is shifted to the north-east with respect to the deeper one. Moreover the two clusters are separated by a gap ~ 3 km wide. Both clusters show a plane dipping to the south-west with a dip of ~ 70°.

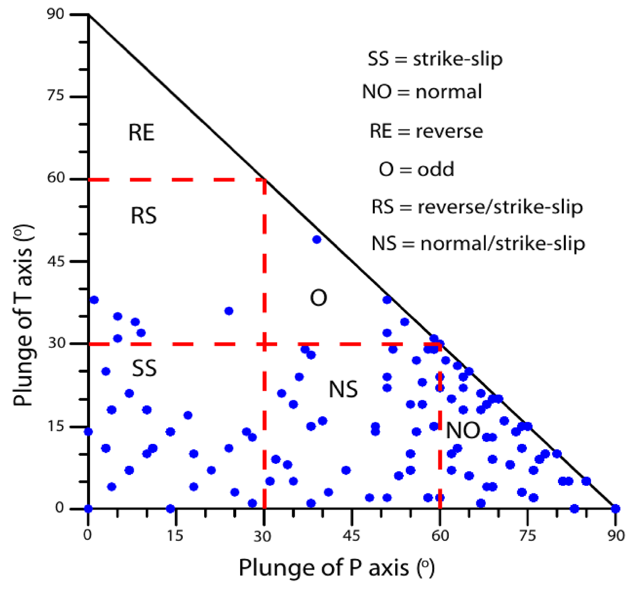


b) Always within the Marsica area, beneath the Serra Lunga in Val Roveto, from April 2009 to September 2010, we recorded a cluster of 156 events with magnitude ranging from 1.0 to 2.7 with hypocentral depth range 8.9-10.7 km. This cluster is located around 12 km to the north-west of the Campoli Appennino swarms and it plays an important role in the determination of the stress field in the area.

c) On May 2010, within two days (29-30 May) occurred a swarm of 149 small events all clustered near the locality of Montaquila (Molise). The swarm started with an earthquake of M_L = 3.3 at 6.9 km of depth. The majority of the events are concentrated in the 4.0-13.0 km depth range. Leaving out the main shock local magnitude is ranging from 0.5 to 2.4.

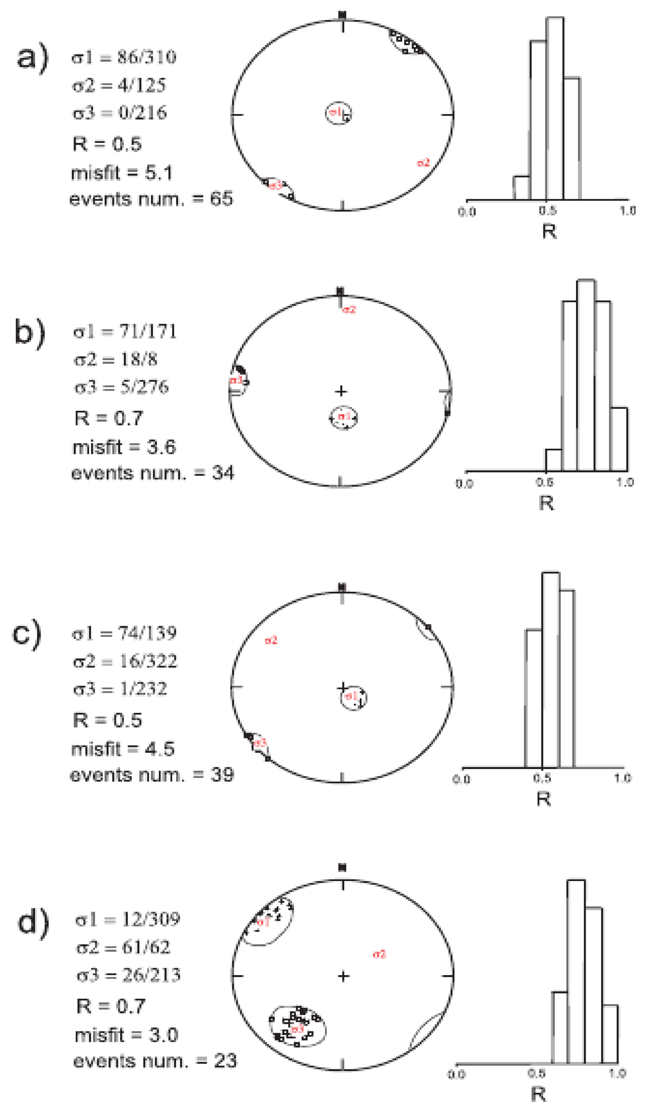
Plunge P- T- Axes

- From the 759 focal mechanism computed (FPFIT code, Reasenberg and Oppenheimer, 1985) we selected 382 well constrained solutions displaying 12 or more observations homogeneously distributed on the focal sphere.
- The majority of the selected focal mechanisms represent pure normal faults and normal faults with strike-slip component (91.3%), whereas the 5.8% are pure strike-slip mechanisms. Only a 1.6% is given by reverse with strike-slip component fault-plane solutions, and a 1.3% are odd focal mechanisms.
- The orientation of the T-axis suggests a widespread NE-SW extension regime.
- This new data set more than quadruples the number of previously available data for regional stress field analysis.

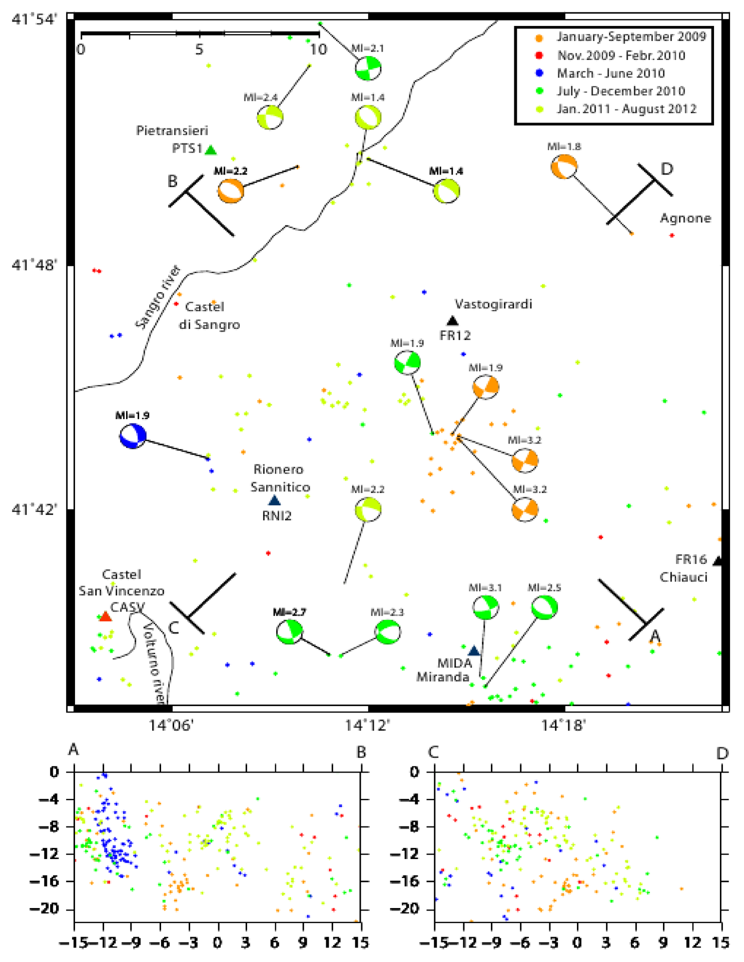


Stress field inversion

We applied the stress field inversion method (Gephart and Forsyth,1984) within the restricted area of the Marsica-Sorano. These data are subdivided into three subsets following the three seismic sequences occurred in the area.
a) The first inversion is performed using the 65 fault plane solutions of the first Campoli Appennino swarm (October 2009). In this inversion average misfit is 5.1°.
b) In the second inversion (34 focal mechanisms of the second Campoli Appennino swarm, May 2011), the stress ratio R near the solution is 0.7, denoting that σ2 is slightly close in its absolute value to σ3.
c) The third inversion is performed using the 39 fault plane solutions of the Sora sequence (February-March 2013). This sequence is slightly shifted to the W and NW with respect to the two Campoli Appennino seismic swarms. Average misfit is 4.5° and the stress ratio R is 0.5, as in the first inversion. These results show clearly that the Marsica-Sorano area is affected by an extensional stress regime with a NE-SW extension. The low values of average misfit in the three inversion performed, suggest an homogeneous stress distribution within the considered area.
d) Moreover, we applied the Gephart method using the 23 fault plane solutions of the Serra Lunga cluster, located around 12 km to the north-west of the Campoli Appennino swarms, into the Val Roveto. In this small dataset strike-slip solutions are predominant. This inversion result is consistent with the NE-SW Apenninic extension stress regime (σ3 sub-horizontal NE-SW directed), but in the small Serra Lunga area a transcurrent right-lateral stress regime is prevailing (σ1 horizontal with a NW-SE direction).

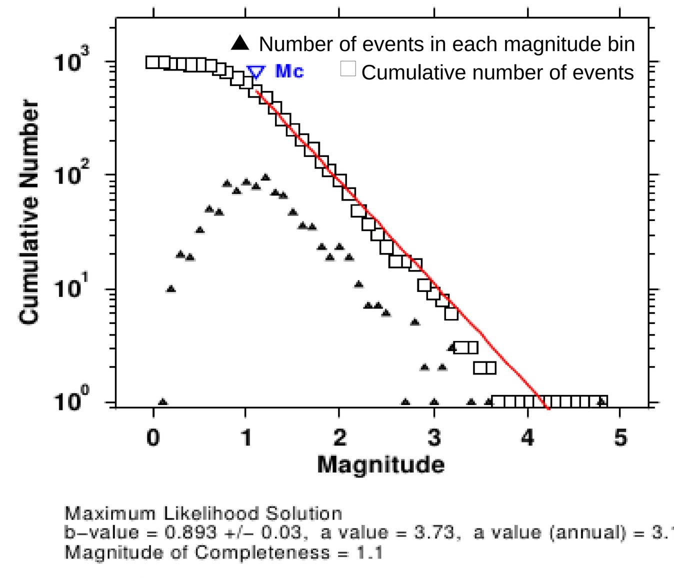


Right-lateral strike-slip solutions



Several fault plane solutions of events located to the east of the Abruzzo National Park, in the area between Vastogirardi and Carovilli (Molise) show right-lateral strike-slip motion. This result appears to be different from the available stress map in the surrounding area. An explanation could be that these small events are the reactivation of pre-existing roughly E-W trending-faults belonging to the transition region from the dextral strike-slip kinematics in the Gargano (Apulia foreland) and Frentani Mountains (2002 Molise earthquake sequence; Di Luccio *et al.*, 2005) to the inner Apenninic belt where normal faults dominate. The pattern of this active deformation in this portion of the study area, together with those observed during the Molise 2002 sequence, is explained in terms of the relative motion between the two Adria microplates, the northern one rotating around an Eulerian pole located at the western margin of the Po valley, and the southern one which includes the Apulian promontory and the Ionian Sea (D'Agostino *et al.*, 2008).

Frequency-Magnitude Distribution (FMD)



The magnitude of completeness (Mc) is determined as the magnitude at which 95% of the data can be modeled by a power law fit (Wiemer and Wyss , 2000).
Following the Gutenberg-Richter law, the b-value reflects the relative proportion among the number of large and small earthquakes in the observed FMD.

References
- D'Agostino, N., Avallone, A., Cheloni, D., D'Anastasio, E., Mantenuto, S., Selvaggi, G., 2008. Active tectonics of the Adriatic region from GPS and earthquake slip vectors. J. Geophys. Res., 113, B12413, doi:10.1029/2008JB005860.
- De Luca, G., Cattaneo, M., Monachesi, G., Amato, A., 2009. Seismicity in central and northern Apennines integrating the Italian national and regional networks, Tectonophysics, doi:10.1016/j.tecto.2008.11.
- Di Luccio, F., Fukuyama, E., Pino, N.A., 2005. The 2002 Molise earthquake sequence: What can we learn about the tectonics of Southern Italy? Tectonophysics, 405, 141-154, doi:10.1016/j.tecto.2005.05.024.
- Gephart, J.W., Forsyth D.W., 1984. An improved method for determining the regional stress tensor using earthquake focal mechanism data: application to the San Fernando earthquake sequence, J. Geophys. Res., 89, 9305-9320.
- Holland, J. H. (1975). Adaptation in Natural and Artificial Systems. University of Michigan Press, Ann Arbor.
- Reasenberg, P., Oppenheimer, D., 1985. FPFIT, FPPLOT and FPPAGE: FORTRAN computer programs for calculating and displaying earthquake fault plane solutions, USGS Open-file Report, 85-730, 109.
- Sambridge, M., and K. Gallagher, 1993. Earthquake hypocenter location using genetic algorithms. Bull. Seism. Soc. Am., vol. 83, no. 5, 1467-1491.
- Wiemer, S., and M. Wyss (2000), Minimum magnitude of complete reporting in earthquake catalogs: Examples from Alaska, the western United States, and Japan, Bull. Seismol. Soc. Am., 90, 859–869, doi:10.1785/0119990114.

For further information please contact alberto.frepoli@ingv.it