FOCAL MECHANISMS OF 171 EVENTS OF THE AQUILA SEQUENCE (Ml>3) AND COMPUTATION OF SITE EFFECT AT THE STATIONS OF THE INGV NATIONAL SEISMIC NETWORK IN CENTRAL APENNINES

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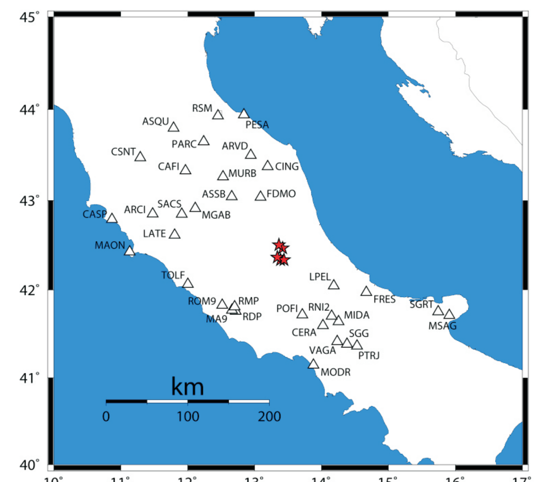
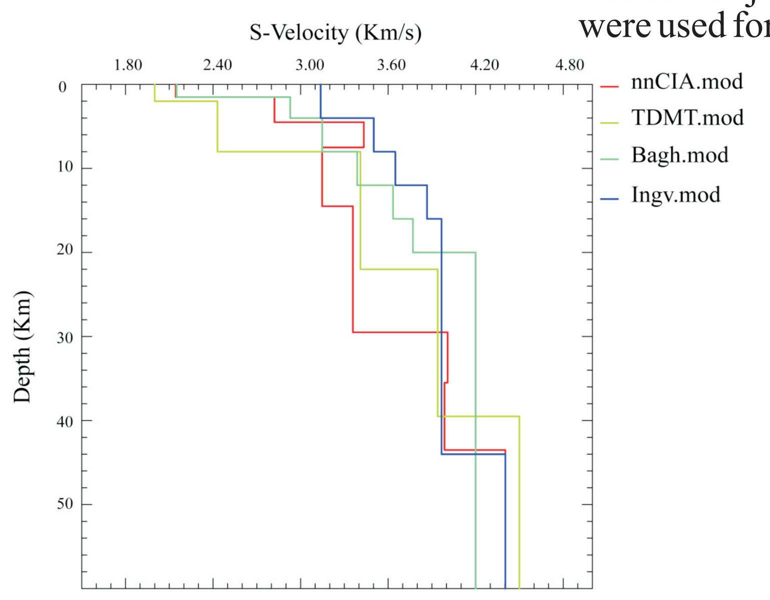
ABSTRACT

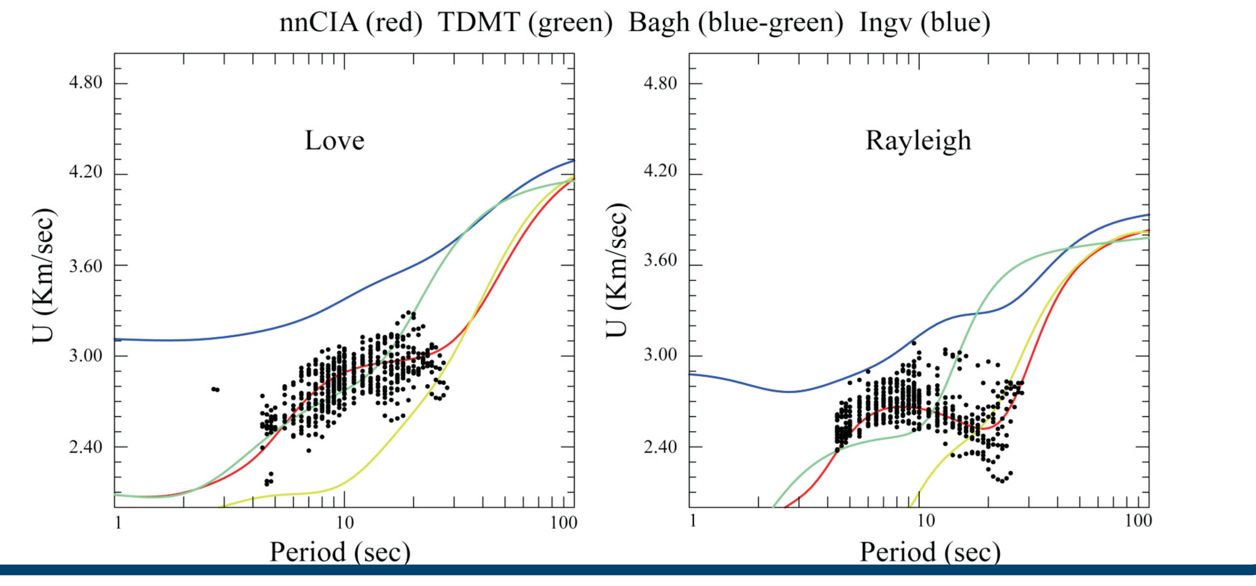
Between October 1st, 2008, and September 24th, 2009, the National Seismic Network recorded 171 earthquakes with 3.0<Ml<5.8 from the Aquila sequence (except the events in the coda of the main shock). We developed a regional velocity model, starting from information taken from the seismic profile CROP11 and performing the inversion of the surface-wave dispersion curves observed on the seismograms of the sequence. We then inverted the broadband waveforms of all the 171 events, and computed their focal mechanisms. Our results show the predominance of normal faulting, which are coherent with the regional stress field that is active in this sector of the Apennines. We then applied a novel technique for the computation of inter-station spectral ratios with respect to a given reference station, in the hypothesis that they are representative of the average site response at each station of the network. Our approach is based on the knowledge of the regional wave propagation, and of the focal mechanisms of each event. Before taking the ratios, we apply a frequency-dependent spectral correction that takes into account both the regional propagation effect, and the differences in radiation pattern that may be calculated at the different stations. For our site effect study we used seismograms with good signal to noise ratios at all frequencies, recorded within 70 Km of each epicenter. We obtain 8 sets of average interstation spectral ratios: a different set for each one of the 8 different reference sites that were chosen within the investigated portion of the national seismic network.

VELOCITY MODEL



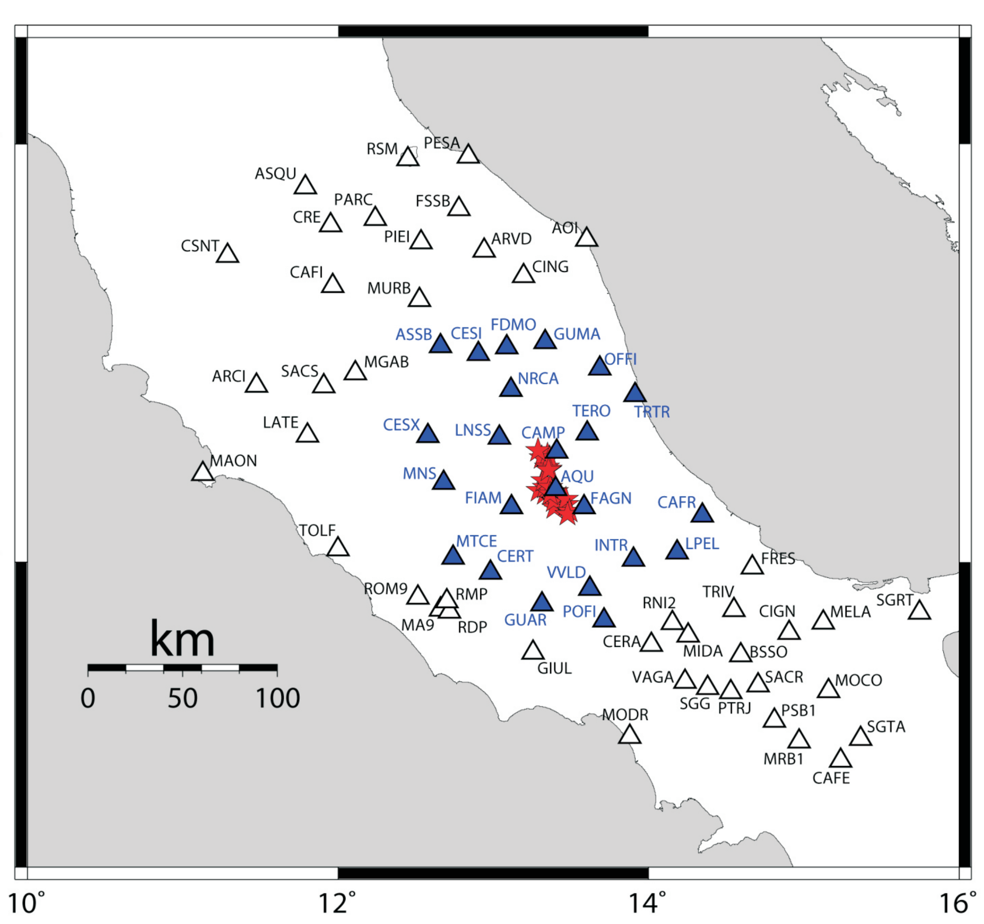
The main purpose of this study was to model the broadband waveforms from the L'Aquila sequence in detail (e.g., ground velocity filtered in the 0.02 - 0.10 Hz band). In order to accomplish this, we used the INGV (ISIDe) locations and origin times, together with the observed waveforms from the L'Aquila aftershocks, and determined the dispersion curves of Rayleigh- and Love-wave group velocities. The figure up on the left shows the stations and the epicenters used in the study. We determined the dispersion over a 400 km-long section, and inverted it for the velocity structure. We started with a layered crustal structure based on Di Luzio et al. (2009, fig 5. 7-8), and permitted the starting model to change in order to fit the observed Love and Rayleigh dispersions. The two figures low compares the observed group velocity dispersions (black dots) to various model predictions. Our model, indicated as **nnCIA.mod** in the center-left Figure, is not constrained very well at depth, since we did not have periods T> 30 sec in the observations. However, it generally fits the dispersion in the 4 - 30 sec period range. We also created another velocity structure based on a joint inversion performed on receiver functions computed at AQU, and on the observed dispersion curves (not shown). Receiver functions were characterized by "ringings", which indicated a thick low velocity layer near the surface. We computed Green's functions also for the joint inversion model. The latter were very similar to those of the **nnCIA.mod** model, which were used for all of the inversions.



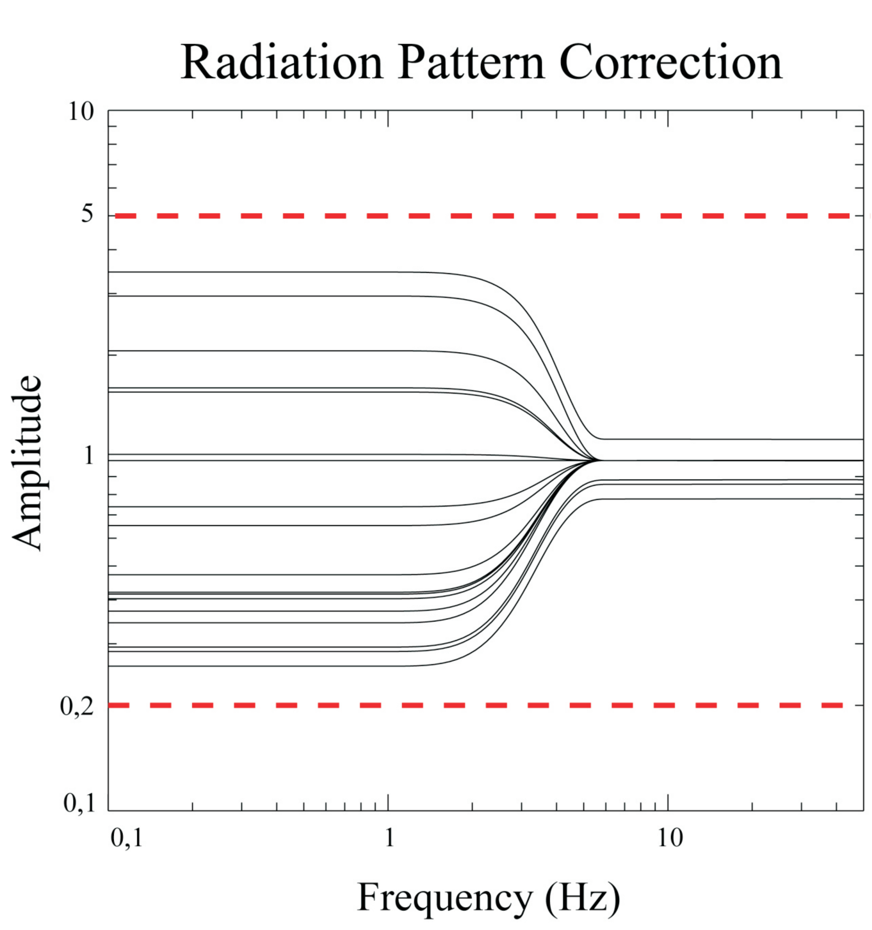


SITE EFFECTS

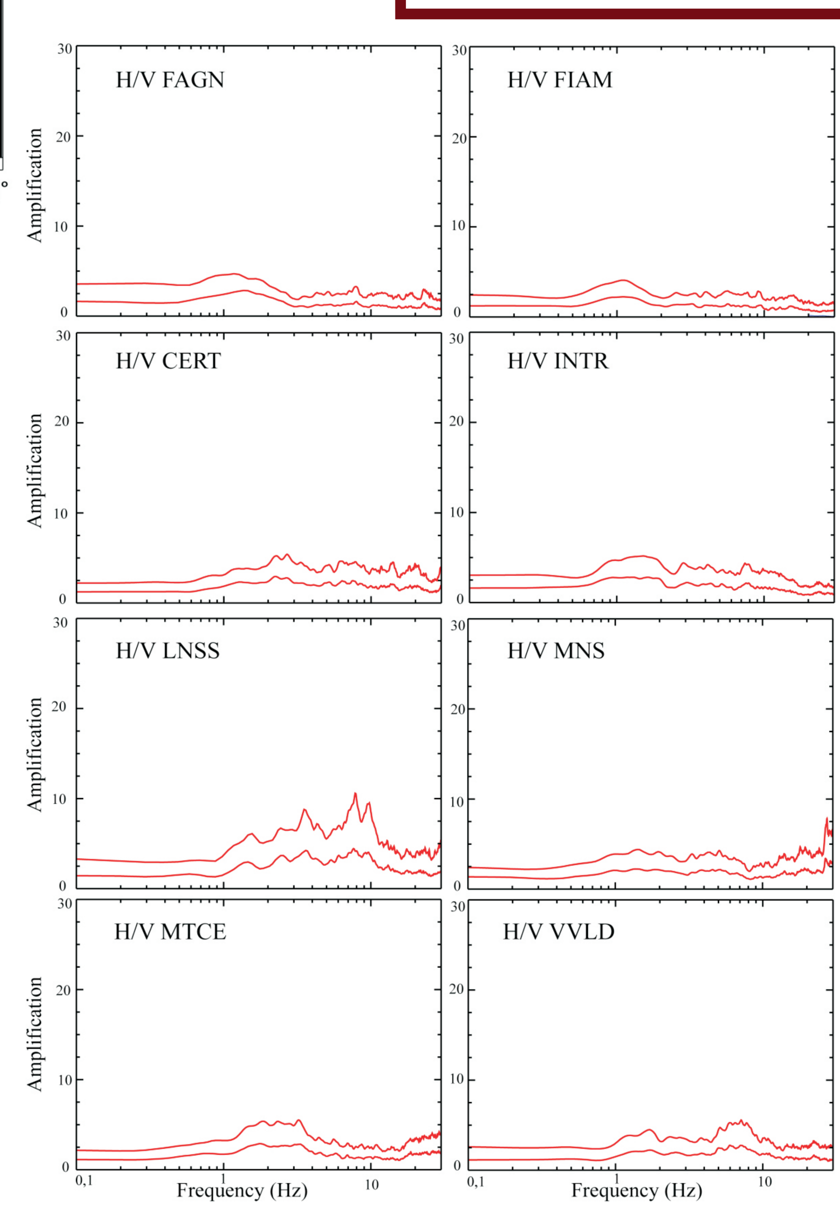
We implemented a novel procedure based on the wave propagation model by Malagnini et al. (2008), and on the source study described above. We wrote a fully automated code in which the site effect calculation is performed through a SAC macro. First, the S wave spectra are corrected for the geometric and anelastic crustal attenuation (Malagnini et al., 2008). The spectra are computed over wave trains starting 1.0 sec before the manually-picked S-wave arrivals, within a time window that does not include surface waves. The length of the time window depends on the dispersion calculated by Malagnini et al. (2008) at 2.0 Hz, and it is also slightly magnitude-dependent. After tapering, de-trending, and removing the average, the Fourier amplitude spectra are computed over the three components of the ground motion. Spectral ratios are taken between the horizontal (vector summation of N-S and E-W spectra) and the vertical Fourier spectra. Finally, inter-station spectral ratios are corrected for the radiation pattern. Such frequency-dependent correction parameter is calculated by computing the Fourier amplitude spectra of synthetic seismograms computed at both stations, correcting them for the geometric attenuation, and taking the spectral ratios. At each station, the inverse of this ratio is the radiation pattern correction. Synthetic seismograms are calculated for the layered velocity structure calibrated during the seismic sequence. Radiation pattern corrections are smoothly forced to get closer to one, following the results by Takemura et al. (2009), who stated that the radiation patterns degrade with increasing frequency, due to crustal scattering, and becomes basically isotropic at frequencies higher than 5 Hz. Degradation of the radiation pattern correction is stronger for increasing epicentral distance



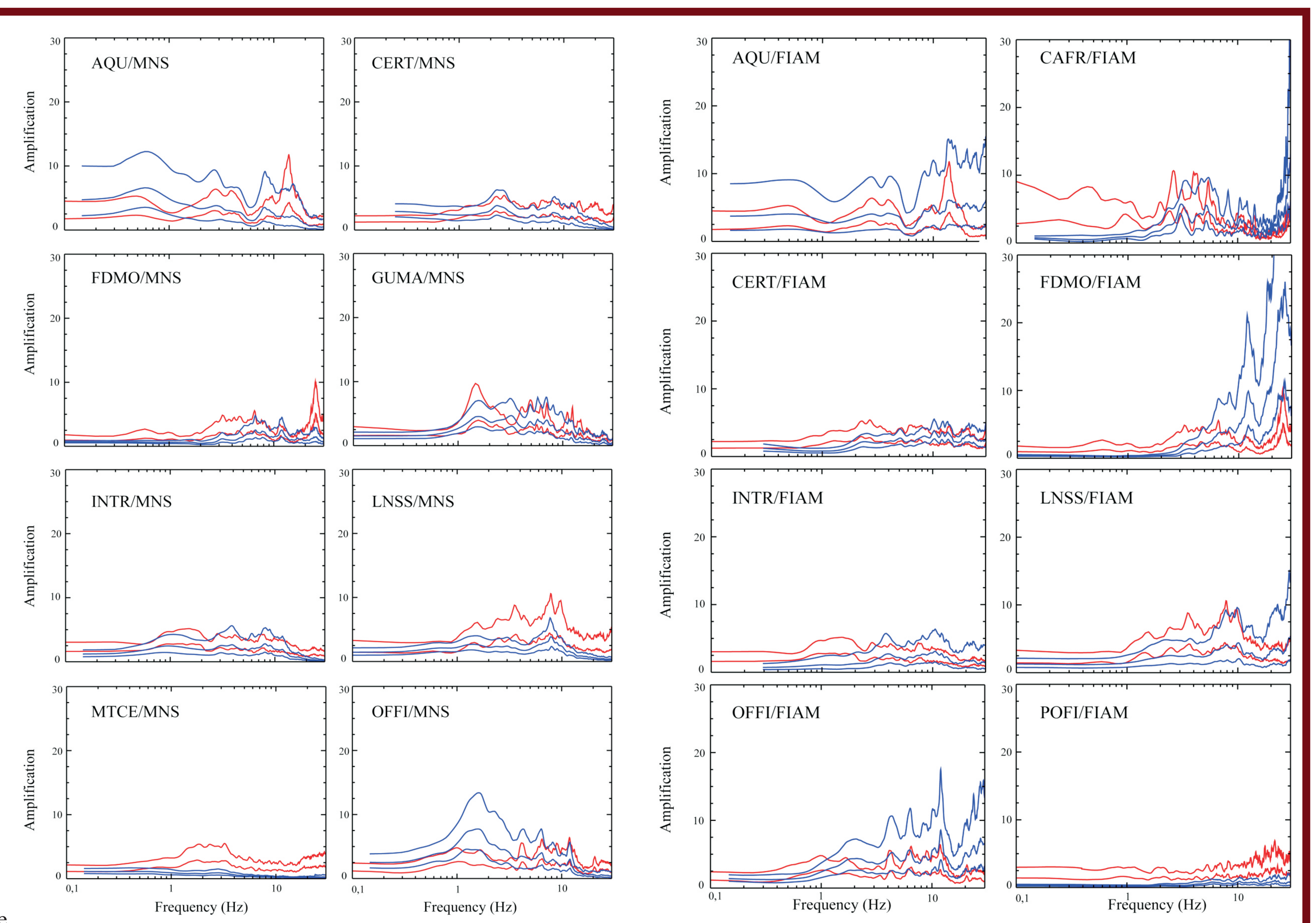
For the study on the interstation spectral ratios we used only the stations for which the epicentral distances are less than 70 Km. Solid blue triangles indicate the stations that meet the requirement. Open triangles indicate stations that were not used. Stars are the locations of the 171 events.



Radiation pattern corrections for spectra of the event occurred on 2009/04/21, at 15:44:36 (Mw 3.53). In this case, station FAGN is chosen as reference.

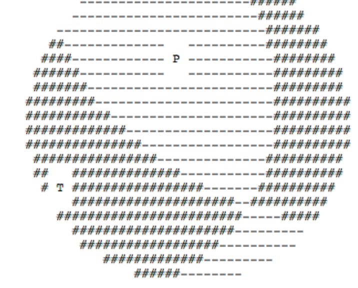


The choise of the eight possible reference sites was based on the ground of flat H/V spectral ratio (red lines: average H/V ratio ± 1σ).



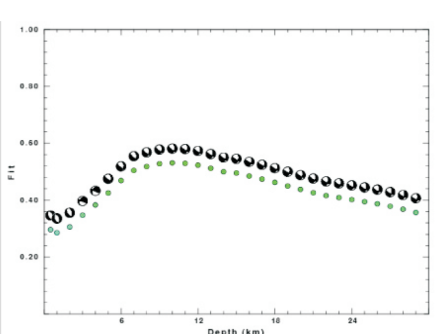
Interstation S-wave spectral ratios for some of the stations within 70 Km of the events. The figure to the left is relative to the reference station MNS; the one to the right to the reference station FIAM (red lines: average H/V ratio ± 1σ; blue lines: average, average ± 1σ)

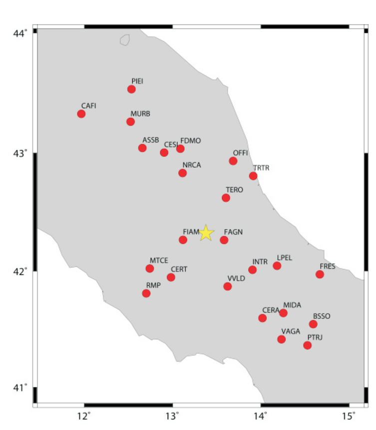
MOMENT TENSOR SOLUTIONS

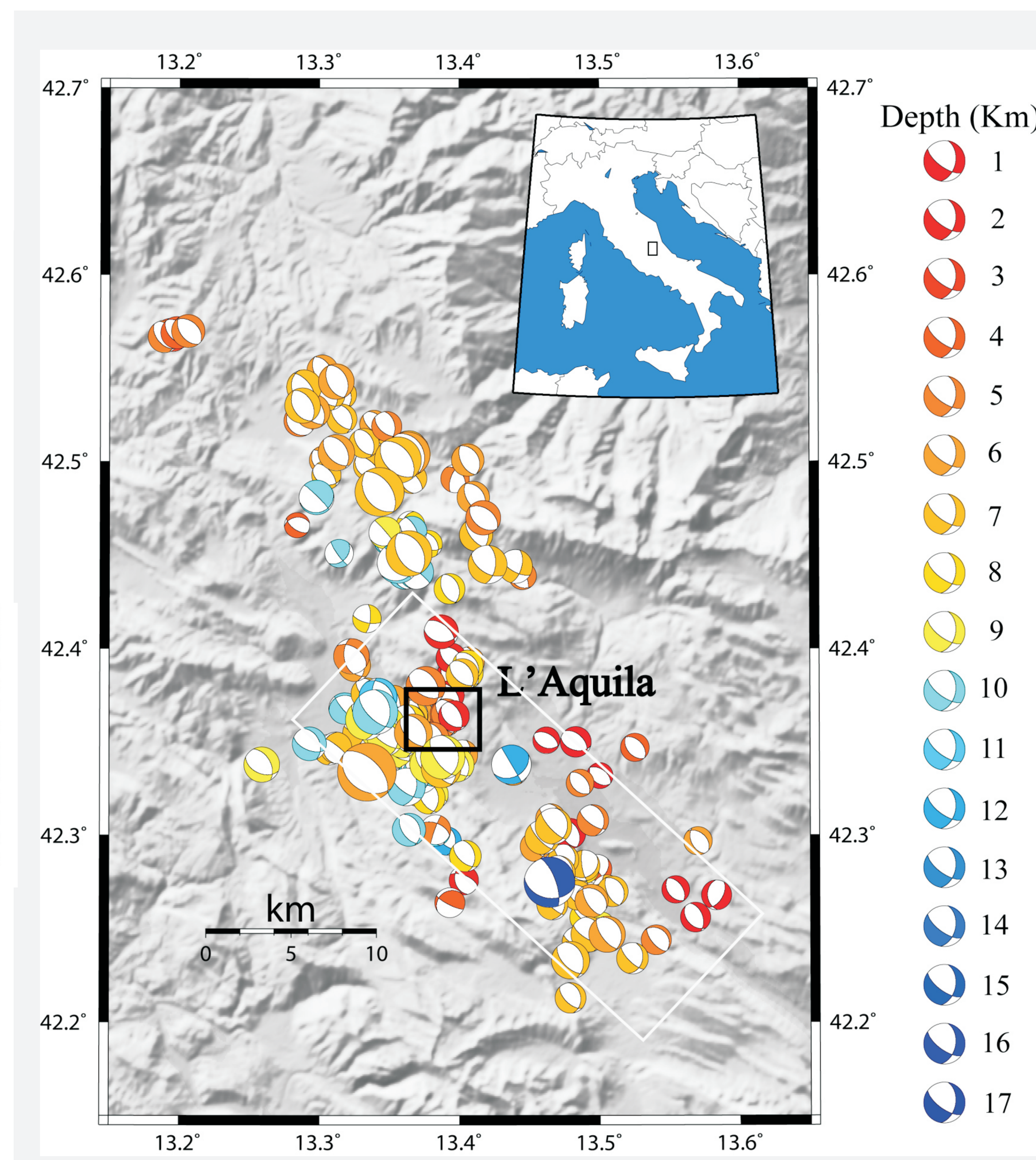


STK = 10
DIP = 45
RAKE = -35
Mw = 4.09
Hs = 9.0

We show one examples of moment tensor solution, for the events occurred on 2009/03/30 at 13:38:38 UTC (Mw 4.09). Here are plotted the beach ball, the waveform fits, and the overall best fit as a function of the centroid depth.







Map of the 171 moment tensor solutions computed on our data set. The colors indicate the depths of the centroids. The distribution of the focal depths is consistent with the presence of different fault planes dipping to the South West.

CONCLUSIONS

We studied the l'Aquila sequence, which started in late 2008. We developed a regional velocity model, by starting from the seismic profile CROP11 (Di Luzio et al., 2009) and inverting the observed surface-wave dispersion curves. We then computed a set of Green's functions and used them to grid-search the best moment tensor solution for each of the 171 events in our data set.

Interstation spectral ratios were computed on direct S-waves by means of a novel technique, using the results of Malagnini et al. (2008) to correct the observed spectra for the regional propagation. The focal solutions indicated here were used to correct the interstation spectral ratios for the different radiation patterns. If we knew the absolute response of any one of the investigated sites, we could have used it to infer the absolute responses of all the other stations. Unfortunately, we did not have such information, neither did we know if any one of the eight sites characterized by a flat H/V ratio actually behaves as a reference (flat response, close to unity). In any case, we provided a method that can be used to obtain inter-station site terms even when the different sites are not close to one another, or when they have very different backazimuths.

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