The 6th April 2009, Mw 6.3, L'Aquila sequence: weak and strong motion data recorded by RAIS temporary stations

Short title: **L'Aquila temporary network**

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Abstract

The aim of this work is the sharing of waveforms recorded by several INGV temporary stations (managed by the department of Milano-Pavia; hereinafter INGV MI-PV), installed after the occurrence of the 06th April 2009, Mw 6.3, L'Aquila earthquake (Central Italy). The work synthesizes the activities conducted in the field by the INGV MI-PV working group in the three months following the mainshock.

The field activities have been developped in different phases. Starting from the 7th of April 2009, the temporary stations have been installed in correspondence of the more damaged areas. The scope was to record the strongest aftershocks in the days which followed the main event; in this phase the stations were composed of a 6 component acquisition system coupled with both a weak and a strong-motion sensor. After the first month, the second phase of installation has been devoted to investigate the seismic response of the sites located in the epicentral area, involving villages in a radius of about 20 km from the epicenter of the 6th April mainshock. In this way the stations have been installed in sites with different lithologic and geomorphologic conditions. The instruments worked from April 7 to July 14, 2009; in this period 9,155 aftershocks (134,262 accelerometric waveforms and 133,242 velocimetric waveforms), with ML up to 5.3 were recorded.

This work describes the dataset of earthquake waveforms recorded with both velocity and acceleration transducers. Selected waveforms, with the corresponding information concerning instrumental characteristics, installation

sites and recorded earthquakes, are available through the ftp://ftp.mi.ingv.it/download/RAIS-TS_rel01/.

1. Introduction

On April 6, 2009, a Mw 6.3 normal faulting event (Ameri *et al.*, 2009; Anzidei *et al.*, 2009; Cirella *et al.*, 2009) struck the Abruzzo region close to the city of L´Aquila (Central Italy). Soon after the mainshock, the first emergency structure of the National Earthquake Centre of INGV (INGV-CNT, http://cnt.rm.ingv.it/) was activated, in order to install in the epicentral area a real-time temporary seismic network (Chiarabba *et al.*, 2009) with the aim to capture the migration of the hypocenter of the aftershocks. In the meantime the INGV MI-PV made available the mobile stations of the RAIS (Strong-motion network of Northern Italy, http://rais.mi.ingv.it; Augliera *et al.*, 2009), in order to realize a high density temporary network. In this way the INGV MI-PV operated together with INGV-Rome1 (http://www.roma1.ingv.it/) and the Helmholtz Centre, Potsdam (http://www.gfz-potsdam.de/portal/gfz/home) in the framework of a coordinated experiment (Cultrera et al., 2010).

A relevant number of stations were installed in the area surrounding the town of L'Aquila (upper Aterno valley), nearby or inside the most damaged villages (Galli et al., 2009) and where coseismic surface effects have been observed (Emergeo Working Group, 2010).

In the first month after the 6th April 2009, Mw 6.3, L'Aquila mainshock, the RAIS temporary stations (hereinafter RAIS-TS) were mainly installed in correspondence of the villages that undergone the highest damages. In this

phase, the stations were installed also with the aim to record the more energetic aftershocks and to evaluate the presence of possibile nonlinear effects; in particular, the accelerometric sensors have been used to avoid the signal saturation.

In a second time, the RAIS-TS stations were moved in several areas (up to 20 km far from the town of L'Aquila, see Figure 1) in order to evaluate the local site response using ambient noise and/or earthquake recordings. This phase of installation was performed in agreement with the research-groups operating in the area, with the aim to investigate a relevant number of areas but without superimposition of recording stations.

This work describes the features of the data collected by RAIS-TS in the epicentral area of the L' Aquila mainshock (Mw6.3) during the three months following the 6th April 2009. The RAIS-TS recorded more then 267,000 waveforms related to 9,155 aftershocks. In general the selected waveforms refer to earthquakes with epicentral distance up to 65 Km, the 93 % of which were recorded at distances < 30 Km. In particular, 15 aftershocks with magnitude greater than 4.0, 2 of which had magnitude greater than 5.0, were recorded in the first month (table I). The aftershocks have been recorded in 29 sites, corresponding to 25 localities inside the province of L'Aquila (table II). The main scope of this work is the data dissemination of the collected waveforms, in order to stimulate the research associated to the April 6, 2009, L'Aquila earthquake, with the hope that it can be useful for both safety and awareness of people.

2. Data Acquisition

Starting from April 7, 2009, several instruments of the RAIS-TS (fig. 1) were installed in the epicentral area of the April 6, 2009, L'Aquila event (Mw 6.3), to achieve the abovementioned tasks regarding both seismic monitoring and local site effects investigation. Due to the limited number of available instruments, a particular installation strategy was adopted in order to realize different network configurations during the evolution of the sequence. The stations, working globally from April 7 to July 14, 2009, were installed in sites with different lithologic and geomorphologic conditions, according to 4 different network configurations that correspond to the following time periods:

7-26 April, 2009: in this first period 5 RAIS-TS stations were installed in correspondence of the more damaged villages (Galli et al., 2009). Four 6-component stations (with 3-component velocimetric and 3-component accelerometric transducers) and one 3-component station (3-component velocimetric sensor) were installed near the municipalities of Pescomaggiore, Paganica, Onna, Fossa, S. Eusanio Forconese (fig. 1).

27 April – 8 June, 2009: during this period the number of RAIS-TS increased to 7 (four 6-component and three 3-component instruments), installed in selected areas located in the municipality of L'Aquila (near source): Camarda, Bazzano, Sant'Antonio, San Giacomo, Sant'Elia, Sassa Zona Polivalente and Cese di Preturo (fig. 1). The new configuration of the network was realized in order to investigate the seismic response of the areas, assessing the soil

resonance frequencies through empirical analysis of the recorded events: horizontal to vertical spectral ratios (H/V) on earthquakes (Lermo and Chavez-Garcia, 1993) and receiver functions (Borcherdt, 1970).

9-22 June, 2009: in this period the network was composed of 8 stations (two 6-component and six 3-component instruments) that were installed in the areas of the Aterno valley between 10 and 20 km SE of the L'Aquila town, between the municipalities of Fossa and Pedicciano (fig. 1). The instrumentation were installed inside the municipalities of Fossa (2 stations), Fagnano, Casentino, Villa S. Angelo, Stiffe, Vallecupa, Pedicciano.

23 June – 14 July, 2009: in this last period the RAIS-TS were moved both in NW and SE directions in order to complete the geophysical characterization of the Aterno valley. The last phase included a total of 8 installations, 5 of which in the municipalities of Poggio Picenze, S. Demetrio ne' Vestini, Barisciano (2 stations) and S. Pio delle Camere (sites located SE of L'Aquila) and 3 in correspondence of the municipality of Arischia, located about 10 Km NW of L'Aquila (fig. 1).

In general the seismic stations (see table III) were equipped by 5s or 1s Lennartz velocimetric sensors and Kinemetrics Episensors (strong motion sensor), coupled with 24-bits Reftek 130 digital recorders (both 3 and 6 channels). The time code adopted is based on GPS and the supply was assured by solar panel with service battery. Where possible, sensors were buried below 30 cm of soil. The seismic data were recorded in local memory card and

instruments were sheltered in the watertight box. Figure 2 shows the seismicity recorded during the whole abovementioned periods by the RAIS-TS.

3. Data selection.

All stations recorded in continuous mode (data were stored in 1 hour long data files), so it was possible to recover the time series related to each event from continuous signals. In order to extract the waveforms recorded from the RAIS-TS in the whole considered period, we refer to the hypocenters reported in the INGV official seismic bulletin (ISIDE - Italian Seismological Instrumental and Parametric Data-Base; http://iside.rm.ingv.it/iside/standard/index.jsp, last accessed on 4th December 2009).

The ISIDE reference location file is composed of Quasi-Real time revised locations and this knowledge comes from the Italian National Seismic Surveillance, an advanced real-time system for seismic data analysis operated by the INGV-CNT in Rome. It gives a first location of any Italian earthquake, starting from a minimum ML of 1.8, within 40 seconds from its origin time, and a definitive location within 5 minutes. Although all of the events detected by the Italian National Seismic Network are located automatically, the ISIDE reports only the list of locations revised by the Seismologist which is in charge for the seismic surveillance activity when the earthquake occurs. This localization is the best evaluation of the hypocenter parameters during the evolution of a seismic sequence.

In order to make available the recorded waveforms of the L'Aquila sequence in a short period, we extracted the data from 07 April 2009 at 07:10 (GMT) to 14 July 2009 at 15:50 using the ISIDE. We considered all the events, without

magnitude selection, occurred within a rectangular area limited between 42.15 and 42.70 degrees in latitude North and between 13.00 and 13.80 degrees in longitude East. For all the events, the reference time was set to the origin time of the earthquake. We consider a pre-event window for data extraction of 30 seconds and a post-event window with a duration that depends on the magnitude of the event (see table IV). The final events list includes a total number of 9,155 earthquakes with ML up to 5.3 (fig. 3). Table I reports an example of the event list for the earthquakes with magnitude greater than 4.0. The complete list of the extracted dataset is available on ftp-site.

The dataset is composed of a total number of 267,504 waveforms, 134,262 of which are strong motion waveforms and 133,242 are velocimetric data. Figure 4 shows the magnitude vs. epicentral distance distribution of the whole dataset. The selected earthquakes were recorded by a variable number of stations, depending on the network configuration. The coincidence list in Figure 5 shows an example for the events with magnitude greater then 4.0. Even if in this work we operated a selection based on ISIDE, since waveforms have been recorded in continuous mode, further time series can be however recovered from continuous recordings on demand.

4. Data-set structure and data format

Earthquake waveforms were at first extracted from continuous signals and then converted into Little-endian SAC binary files (Tapley and Tull, 1992; http://www.iris.washington.edu/software/sac/). Each time series was

singularly written on the SAC file data-section as evenly-sampled data sequence. Consequently, the SAC header variables LEVEN and IFTYPE were set to TRUE and ITIME, respectively. All data are sampled at 100 sps and data values are expressed in counts. Ground motion units can be obtained through the SAC header variables USER0 and USER1, respectively set as sensitivity (V/m/s and V/g for velocimetric ad accelerometric sensors, respectively) and digitization constant (V/count) and KUSER0 (gain). Extracted waveforms were baseline corrected using the SAC command RTREND that removes any linear trend from data and media removed using the SAC command RMEAN. Waveforms were not corrected for the instrument response and not filtered. The SAC-header parameters were generally set according to the conventions adopted by the SAC Users Manual (http://www.iris.edu/manuals/sac/manual.html) with a certain number of variables customized for the present dataset. In the Appendix the complete description of the SAC header variables is reported.

The waveforms data set is organised following an event-code, defined by the origin time of the earthquake (expressed as year, month, day, hour, minute and second), as reported in the ISIDE. The dataset is structured in directories having names corresponding to the event-code. Each directory contains SAC files with the waveforms related to the stations that recorded the corresponding earthquake. File names are composed of four different sections: extraction time (year, month, day, hour, minute and second, defined according to the abovementioned pre-event time that was selected to be 30 s before of the origin time of the earthquake), station code (four characters), channel (according to SEED-format conventions, see below) and file-type (e.g. *.sac*).

The SEED-format convention for the channel naming adopts three characters, each of them describing a single aspect of the data. The first character specifies the general sampling rate and the response frequency band of the instrument: for example "E" stands for “Extremely Short Period instrument with sample rate in the range 80-250 Hz and corner period < 10 s”. The second character specifies the sensor-family: "H" stands for “High Gain Seismometer” and "N" for accelerometer data. The third character specifies the orientation code (Z, N, E for traditional Vertical, North-South, East-West). For more information refer to Appendix A of the SEED - Reference Manual (Incorporate Research Institute for Seismology - IRIS, 2009; http://www.iris.washington.edu/manuals/SEED_appA.htm). For example, following the ISIDE origin time, the event occurred on 9th April 2009 (19:38:16) and recorded by MI01 station (equipped with a Lennartz Le3D-Lite velocimetric sensor, corner period 1s and sampling 100 sps) was extracted at 19:37:46: in this case the name of the related file (included in the folder /20090409193816/) will be 20090409193746_MI01.EHZ.sac

All extracted SAC-waveforms are included in the section /waveforms/ of the dataset in which directories, corresponding to the different earthquakes, are grouped according to four magnitude classes: 3.0 ≤ ML < 5.5 (146 events); 2.0 ≤ ML < 3.0 (1505 events); 1.5 ≤ ML < 2.0 (3673 events); 0.0 ≤ ML < 1.5 (3831 events). Each class corresponds to a uncompressed *tar* archive file, also including the information files of the whole dataset. Information files are subdivided in sections /maps/ and /files/, the former including KML files to display stations and epicentres in an Earth browser such as Google Earth (http://earth.google.com). The section /files/ includes bulletin files;

coincidence files; stations books and instruments information. The complete structure of the dataset is summarized in Figure 6.

5. Conclusions

The dataset presented in this paper consists of more than 267,000 waveforms related to 9,155 aftershocks occurred after the 6th April 2009, Mw 6.3, L'Aquila earthquake and recorded by the RAIS-TS in the period April, 7 – July 14, 2009. The selected waveforms, all available in SAC format, correspond to events with a maximum epicentral distance of 65 Km. In particular, the data set includes 15 events with ML greater then 4, 2 of which with ML greater than 5, recorded at epicentral distances less then 30 Km (table I).

The waveforms have been extracted from signals recorded in continuous mode after selection of the corresponding time windows based on the origin time reported in the ISIDE bulletin. The localizations used for this dataset correspond to the best evaluation of hypocenter parameters available on December 2009. A minimal pre-processing, basically consisting in a linear-trend removing, has been applied to all records. Location parameters and other information about recorded event, station characteristics and instrumental settings have been included in the SAC file header. It is worth noting that, in the case of energetic events recorded by stations close to the epicenter, the weak motion channels (velocimetric sensor) show saturated waveforms (see dashed line in the bottom panel of fig. 4 and fig. 7). On the contrary the strong motion stations, that recorded all strongest aftershocks, can show low quality data (in term of signal to noise ratio) related to weak motions (M_L lower than

1.5), especially if recorded at distances higher than about 20 km. In any case the database described in this work includes all records. It will be responsability of final users to point their attention about the previous considerations.

The maximum recorded Peak Ground Acceleration was 0.69 g at 5.4 Km epicentral distance (station MI05), during the April 7, 2009, ML 5.3, earthquake (fig. 8).

As it is usual in a seismic sequence, the first period of activity is characterized by a high seismic rate with a large number of events in short time periods. Waveforms belonging to different earthquakes often overlap in the same time window (fig. 9).

The 267,504 selected waveforms and the corresponding information about instruments, installation sites and recorded earthquakes, are downloadable from ftp://ftp.mi.ingv.it/download/RAIS-TS_rel01/

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Table I. Earthquake list (ML≥4.0). The focal parameters come from ISIDE bulletin (http://iside.rm.ingv.it/iside/standard/index.jsp, last accessed on 4/12/2009).

Event ID	Data	Origin Time (GMT)	Latitude (° N)	Longitude (° E)	Depth (Km)	ML
20090407092628	2009-04-07	09:26:28	42.342	13.388	10.2	4.7
20090407174737	2009-04-07	17:47:37	42.275	13.464	15.1	5.3
20090407213429	2009-04-07	21:34:29	42.380	13.376	7.4	4.2
20090408225650	2009-04-08	22:56:50	42.507	13.364	10.2	4.3
20090409005259	2009-04-09	00:52:59	42484	13.343	15.4	5.1
20090409031452	2009-04-09	03:14:52	42.338	13.437	18.0	4.2
20090409043244	2009-04-09	04:32:44	42.445	13.420	8.1	4.0
20090409193816	2009-04-09	19:38:16	42.501	13.356	17.2	4.9
20090413211424	2009-04-13	21:14:24	42.504	13.363	7.5	4.9
20090414201727	2009-04-14	20:17:27	42.530	13.288	10.4	4.1
20090423151408	2009-04-23	15:14:08	42.247	13.492	9.9	4.0
20090423214900	2009-04-23	21:49:00	42.233	13.479	9.3	4.0
20090622205840	2009-06-22	20:58:40	42.446	13.356	14.2	4.5
20090703110307	2009-07-03	11:03:07	42.409	13.387	8.8	4.1
20090712083851	2009-07-12	08:38:51	42.338	13.378	10.8	4.0

Table II. RAIS temporary stations. In the last column a preliminary soil (*S*) classification is reported (R=rock and S=soft). *V Sens*. and *A Sens* indicate velocimetric and accelerometric sensors respectively. *S Time* is the starting time, *E. Time* is the ending time. *Lon*, *Lat* and *EL* indicate Longitude, Latitude and Elevation.

Code	Locality	Lon (° E)	Lat (° N)	EL (m)	V. Sens.	A. Sens.	S. Time (d/m/y hh:min)	E. Time (d/m/y hh:min)	S
MI01	Pescomaggiore	13.5098	42.3580	740	Le3D-Lite	FBA ES-T	07/04/09 07:14	27/04/09 11:14	R
MI02	Paganica	13.4743	42.3545	648	Le3D-5s	FBA ES-T	07/04/09 08:38	29/04/09 07:38	S
MI03	Onna	13.4757	42.3274	581	Le3D-5s	FBA ES-T	07/04/09 11:35	09/06/09 09:00	S
MI04	Fossa	13.4814	42.3031	612	Le3D-Lite	-	07/04/09 15:03	27/04/09 09:14	R
MI05	S. Eusanio Forconese	13.5252	42.2895	585	Le3D-5s	FBA ES-T	07/04/09 16:49	28/04/09 08:05	S
MI06	Camarda	13.4979	42.3894	807	Le3D-Lite	FBA ES-T	27/04/09 14:18	09/06/09 08:48	S
MI07	Bazzano	13.4459	42.3362	662	Le3D-Lite	FBA ES-T	27/04/09 17:14	09/06/09 08:14	S
MI08	Sant'Antonio	13.3713	42.3574	650	Le3D-Lite	FBA ES-T	28/04/09 13.12	09/06/09 10:12	S
MI09	San Giacomo	13.4144	42.3658	782	-	FBA ES-T	28/04/09 15.20	09/06/09 08:20	S
MI10	Sant'Elia 1	13.4307	42.3368	607	Le3D-5s	FBA ES-T	29/04/09 11:32	08/06/09 14:53	S
MI11	Sassa Zona Polivalente	13.3183	42.3659	657	Le3D-5s	-	29/04/09 15:58	08/05/09 11:00	S
MI12	Cese di Preturo	13.2910	42.3716	672	-	FBA ES-T	29/04/09 17:00	09/06/09 11:49	S
MI13	Sassa Zona Polivalente	13.3183	42.3659	657	-	FBA ES-T	08/05/09 15:12	08/06/09 13:12	S
MI14	Villa Sant'Angelo	13.5365	42.2706	587	Le3D-5s	-	09/06/09 15:15	24/06/09 07:15	S
MI15	Vallecupa	13.5740	42.2532	680	Le3D-5s	FBA ES-T	10/06/09 15:46	22/06/09 15:46	S
MI16	Pedicciano	13.5916	42.2411	749	Le3D-5s	-	10/06/09 17:52	25/06/09 09:08	S

Code	Locality	Lon (° E)	Lat (° N)	EL (m)	V. Sens.	A. Sens.	S. Time (d/m/y hh:min)	E. Time (d/m/y hh:min)	S
MI18	Fossa	13.4904	42.2970	622	Le3D-5s	-	11/06/09 08:14	22/06/09 13.14	S
MI19	Casentino	13.5114	42.2806	579	-	FBA ES-T	11/06/09 09:56	24/06/09 08:56	S
MI20	Stiffe	13.5464	42.2567	609	-	FBA ES-T	11/06/09 11:24	24/06/09 08:24	S
MI21	Fossa	13.4928	42.2827	741	Le3D-5s	-	11/06/09 15:54	22/06/09 13:54	R
MI22	Vallecupa	13.5767	42.2534	692	Le3D-5s	FBA ES-T	12/06/09 17:20	25/06/09 07:55	R
MI23	Arischia	13.3370	42.4185	862	Le3D-5s	FBA ES-T	23/06/09 16:30	14/07/09 09:30	S
MI24	Arischia	13.3498	42.4228	1052	Le3D-5s	-	23/06/09 13:40	14/07/09 08:30	R
MI25	Arischia	13.3437	42.4146	810	Le3D-5s	-	23/06/09 10:10	14/07/09 09:15	S
MI26	S. Demetrio ne' Vestini	13.5630	42.2914	697	-	FBA ES-T	24/06/09 12:06	14/07/09 11:06	S
MI27	San Pio delle Camere	13.6552	42.2819	807	-	FBA ES-T	24/06/09 14:29	14/07/09 12:29	S
MI28	Poggio Picenze	13.5370	42.3186	715	Le3D-5s	-	24/06/09 16:14	13/07/09 08:14	S
MI29	Barisciano	13.6035	42.3354	1191	Le3D-5s	FBA ES-T	25/06/09 12:50	14/07/09 11:50	R
MI30	Barisciano	13.5944	42.3205	899	Le3D-5s	-	25/06/09 14:50	13/07/09 15:50	S

Table III. Instrumentation.

Seismic sensors					
type	**name**	**natural frequency (Hz)**	**sensitivity**	**poles**	**zeros**
Velocimeter	Lennartz LE-3D/5s	0.2	400 V/m/s	-0.888 + 0.888j -0.888 - 0.888j -0.220 + 0.000j	Triple zero at the origin
Velocimeter	Lennartz LE-3Dlite	1.0	400 V/m/s	-4.444 + 4.444j -4.444 – 4.444j -1.083 + 0.000j	Triple zero at the origin
Accelerometer	Kinemetrics Episensor FBA ES-T	200	10 V/g		

Seismic recorder
Reftek 130-01
3 or 6 Channel recording
Resolution 24 bit
Clock: GPS
Sampling 100 Hz

Table IV. Selection criteria for waveform extraction. Increasing post-event times are related to increasing ML.

Magnitude Class	**Pre-event time (s)**	**Post-event time (s)**	**Number of Events**
M >= 4.0	30	240	15
3.0 <= M < 4.0	30	150	131
2.0 <= M < 3.0	30	90	1505
1.0 <= M < 2.0	30	60	6984
M < 1.0	30	30	520

FIGURE CAPTIONS:

Fig. 1. RAIS-TS stations: coloured triangles indicate the location of the temporary stations installed in the different periods.

Fig. 2. RAIS-TS recorded events: each panel shows the seismicity and the station distribution in each considered period.

Fig. 3. Selected earthquakes: magnitude distribution (blue symbols) and cumulative number of events vs magnitude (red symbols).

Fig. 4. Magnitude vs epicentral distance distribution of the recorded events. Top panel: records from strong motion sensors; bottom panel: records from weak motion sensors. In both panels, the data located above and below the dashed lines indicate possible saturated (for velocimeters, bottom panel) or records with low signal-to-noise ratio (for the accelerometers, top panel) respectively.

Fig. 5. Coincidence list of the dataset events (M≥4.0). STATION: a= accelometer; v = velocimeter. COMPONENT: N=North-South; E=East-West; Z=Up-Down. For each event and for each station the existing components are marked by '+'

Fig. 6. Dataset structure (see text for explanation).

Fig. 7. 7th April 2009, ML=5.3, aftershock recorded at MI05 station by a 6-component acquisition system equipped with both strong motion (HNE, HNN and HNZ for East-West, North-South and vertical components) and weak motion sensors (EHE, EHN and EHZ for East-West, North-South and vertical components). It is worth noting that the strong motion instrument (last three

time sequences) recorded the event without saturation.

Fig. 8. 7th April 2009, ML=5.3, aftershock recorded at strong motion stations MI01, MI02, MI03 and MI05 (East-West, North-South and vertical components in the top, central and bottom panels, respectively) in the near source (epicentral distances less than 10 Km).

Fig. 9. Waveforms of a ML=1.5 earthquake recorded at station MI01 by a 6-component acquisition system equipped with both weak motion (first 3 seismograms) and strong motion sensors (last 3 seismograms). The temporal scale is expressed in seconds. At least two events are overlapped between 30 and 40 s and a small event occurring before the selected earthquake is also visible (between 10 and 20 s).

Appendix

SAC HEADER

EXAMPLE FILE: 20090408175805_MI02.HNZ.sac

Variable	Description	Possible Values	RAIS-TS field (*)	Typical value
NPTS	Number of points per data component.			18000
B	Beginning value of the independent variable			0.000000e+00
A	Ending value of the independent variable			1.800000e+02
IFTYPE	Type of file	= ITIME {Time series file} = IRLIM {Spectral file---real and imaginary} = IAMPH {Spectral file---amplitude and phase} = IXY {General x versus y data} = IXYZ {General XYZ (3-D) file}		TIME SERIES FILE
LEVEN	TRUE if data is evenly spaced			TRUE
DELTA	Increment between evenly spaced samples			1.000000e-02
DEPMIN	Minimum value of dependent variable			-6.655318e+04
DEPMAX	Maximum value of dependent variable			4.807683e+04
DEPMEN	Mean value of dependent variable			2.723649e-06
O	Event origin time (seconds relative to reference time.)			30
KO	Event origin time identification.			(T0)
KZDATE	Alphanumeric form of GMT reference date			APR 08 (098), 2009
KZTIME	Alphanumeric form of GMT reference time			17:58:05.000
IZTYPE	Reference time equivalence	= IUNKN (Unknown) = IB (Begin time) = IDAY (Midnight of reference GMT day) = IO (Event origin time) = IA (First arrival time) = ITn (User defined time pick n, n=0,9)		BEGIN TIME

Variable	Description	Possible Values	RAIS-TS field (*)	Typical value
KINST	Generic name of recording instrument.		x	RTF130
KSTNM	Station name		x	MI02
CMPAZ	Component azimuth (degrees clockwise from north)		x	0.000000e+00
CMPINC	Component incident angle (degrees from vertical).		x	0.000000e+00
STLA	Station latitude (degrees, north positive)		x	4.235449e+01
STLO	Station longitude (degrees, east positive).		x	1.347428e+01
STEL	Station elevation (meters).		x	6.480000e+02
KEVNM	Event name		x	ABRUZZO
EVLA	Event latitude (degrees, north positive)		x	4.236400e+01
EVLO	Event longitude (degrees, east positive).		x	1.339600e+01
EVDP	Event elevation (meters)		x	8.800000e+00
DIST	Station to event distance (km).			6.535192e+00
AZ	Event to station azimuth (degrees).			9.927607e+01
BAZ	Station to event azimuth (degrees).			2.793286e+02
GCARC	Station to event great circle arc length (degrees).			5.879549e-02
LOVROK	TRUE if it is okay to overwrite this file on disk.			TRUE
USER0	Sensitivity	Velocimetric Lennartz sensor=400; Accelerometer Kinemetrics sensor=10	x	1.000000e+01
USER1	Digitalization constant V/c	1.58997e-06	x	1.589970e-06
USER2	Trend removal	(1=rtrend on; 0=rtrend off)	x	1.000000e+00
USER3	Tapering	On=1; Off=0	x	0.000000e+00
USER4	Mean removal	(1=rmean on; 0=rmean off)	x	1.000000e+00
USER5	filtering procedure	(1=Butterworth filter on; 0= Butterworth filter off)	x	0.000000e+00
KUSER0	Sensitivity unit # gain	Velocimeter sensor=V/m/s Accelerometric sensor=V/g Gain=1 or 32	x	V/g#1

Variable	Description	Possible Values	RAIS-TS field (*)	Typical value
KUSER1	Trace unit	Count	**x**	Count
KUSER2	Sensor model	Episens=Kinemetric Episensor; LE3D-1s=Lennartz Lite 1 second; LE3D-5s=Lennartz 5 seconds	**x**	Episens
NVHDR	Header version number. Current value is the integer 6. Older version data (NVHDR < 6) are automatically updated when read into sac			6
NORID	Origin ID			0
NEVID	Event ID			0
LPSPOL	TRUE if station components have a positive polarity (left-hand rule).			FALSE
LCALDA	TRUE if DIST, AZ, BAZ, and GCARC are to be calculated from station and event coordinates.			TRUE
KCMPNM	Component name	HNZ= Accelerometric vertical component (Up-Down) HNN= Accelerometris orizzontal component (North-South) HNE= Accelerometris orizzontal component (East-West) EHZ=Velocimetric vertical component (Up-Down) EHN= Velocimetric orizzontal component (North-South) EHE=Velocimetric orizzontal component (East-West); SEED convention	**x**	HNZ
KNETWK	Name of seismic network.		**x**	RAIS
MAG	Event magnitude.		**x**	3.200000e+00
IMAGTYP	Magnitude type	= IMB (Bodywave Magnitude) = IMS (Surfacewave Magnitude) = IML (Local Magnitude) = IMW (Moment Magnitude) = IMD (Duration Magnitude) = IMX (User Defined Magnitude)	**x**	Local Magnitude

(*) The user defined parameters of the RAIS-TS network are labeled with “x”.

FIG.1

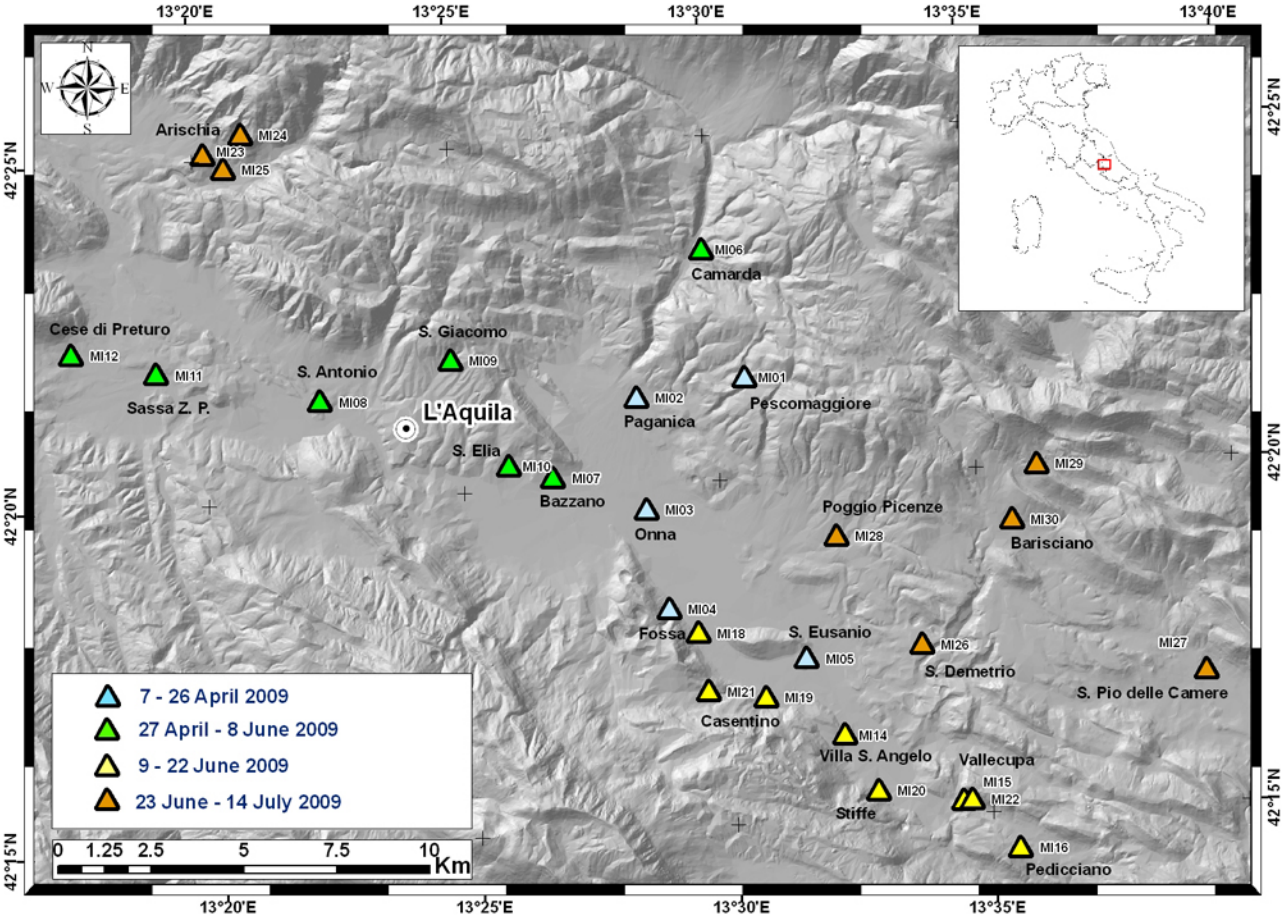

13°20'E
13°25'E
13°30'E
13°35'E
13°40'E
42°25'N
42°20'N
42°15'N
N
S
W
E
Arischia
MI24
MI23
MI25
MI06
Camarda
Cese di Preturo
MI12
MI11
Sassa Z. P.
S. Antonio
MI08
S. Giacomo
MI09
L'Aquila
MI02
Paganica
MI01
Pescomaggiore
S. Elia
MI10
MI07
Bazzano
MI03
Onna
Poggio Picenze
MI28
MI29
MI30
Barisciano
MI04
Fossa
MI18
S. Eusanio
MI05
MI26
S. Demetrio
MI27
S. Pio delle Camere
MI21
MI19
Casentino
MI14
Villa S. Angelo
Vallecupa
MI15
MI22
MI20
Stiffe
MI16
Pedicciano
7 - 26 April 2009
27 April - 8 June 2009
9 - 22 June 2009
23 June - 14 July 2009
0 1.25 2.5 5 7.5 10
Km

FIG.2

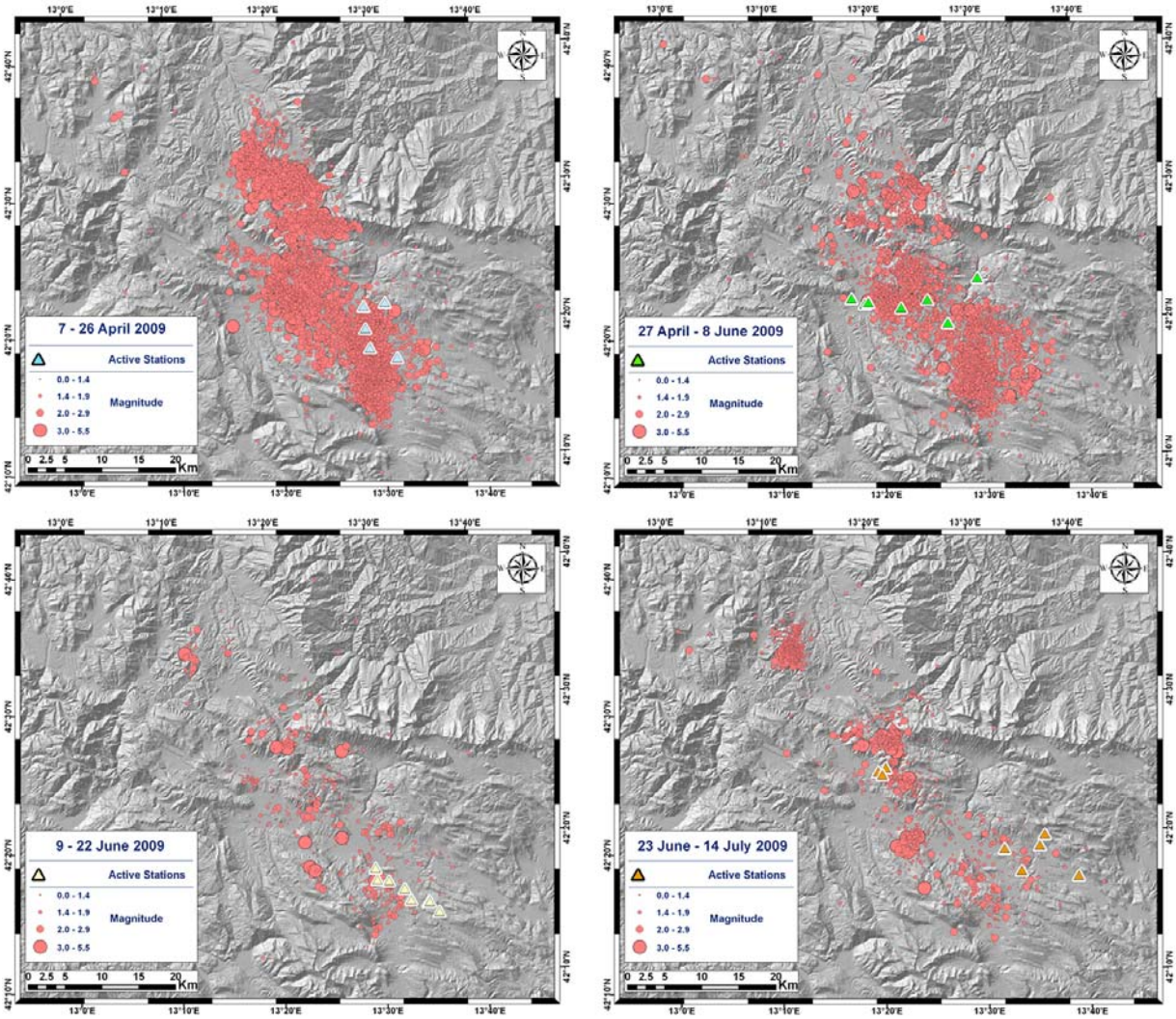

7 - 26 April 2009
Active Stations
Magnitude
0.0 - 1.4
1.4 - 1.9
2.0 - 2.9
3.0 - 5.5
0 2.5 5 10 15 20 Km
27 April - 8 June 2009
Active Stations
Magnitude
0.0 - 1.4
1.4 - 1.9
2.0 - 2.9
3.0 - 5.5
0 2.5 5 10 15 20 Km
9 - 22 June 2009
Active Stations
Magnitude
0.0 - 1.4
1.4 - 1.9
2.0 - 2.9
3.0 - 5.5
0 2.5 5 10 15 20 Km
23 June - 14 July 2009
Active Stations
Magnitude
0.0 - 1.4
1.4 - 1.9
2.0 - 2.9
3.0 - 5.5
0 2.5 5 10 15 20 Km

FIG.3

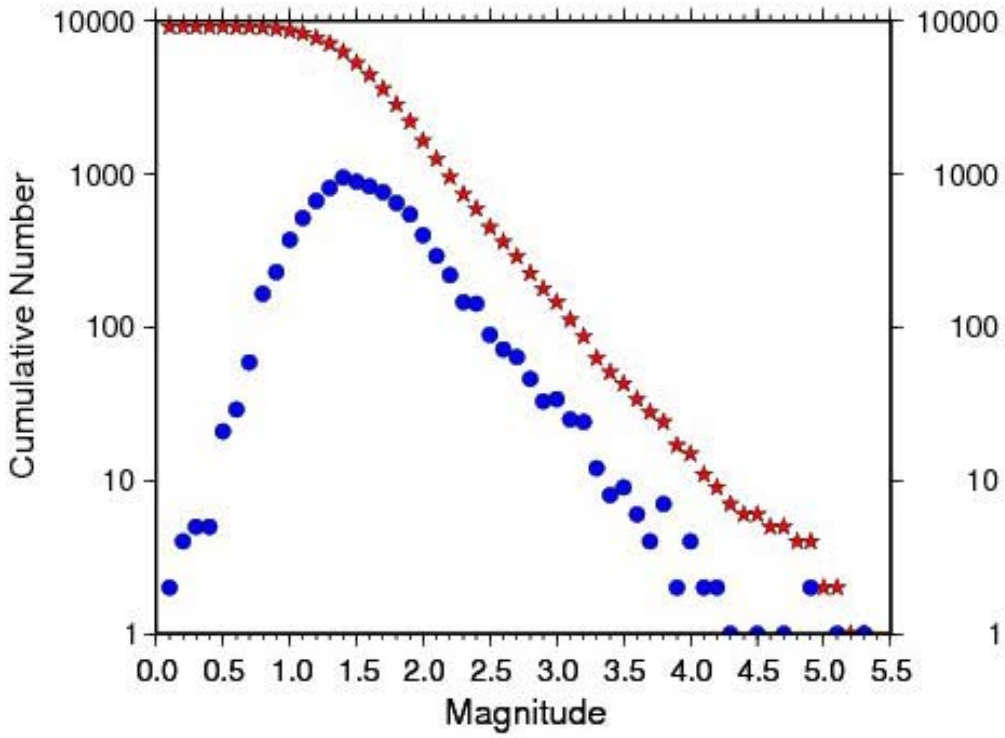

10000
1000
100
10
1
Cumulative Number
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Magnitude

FIG.4

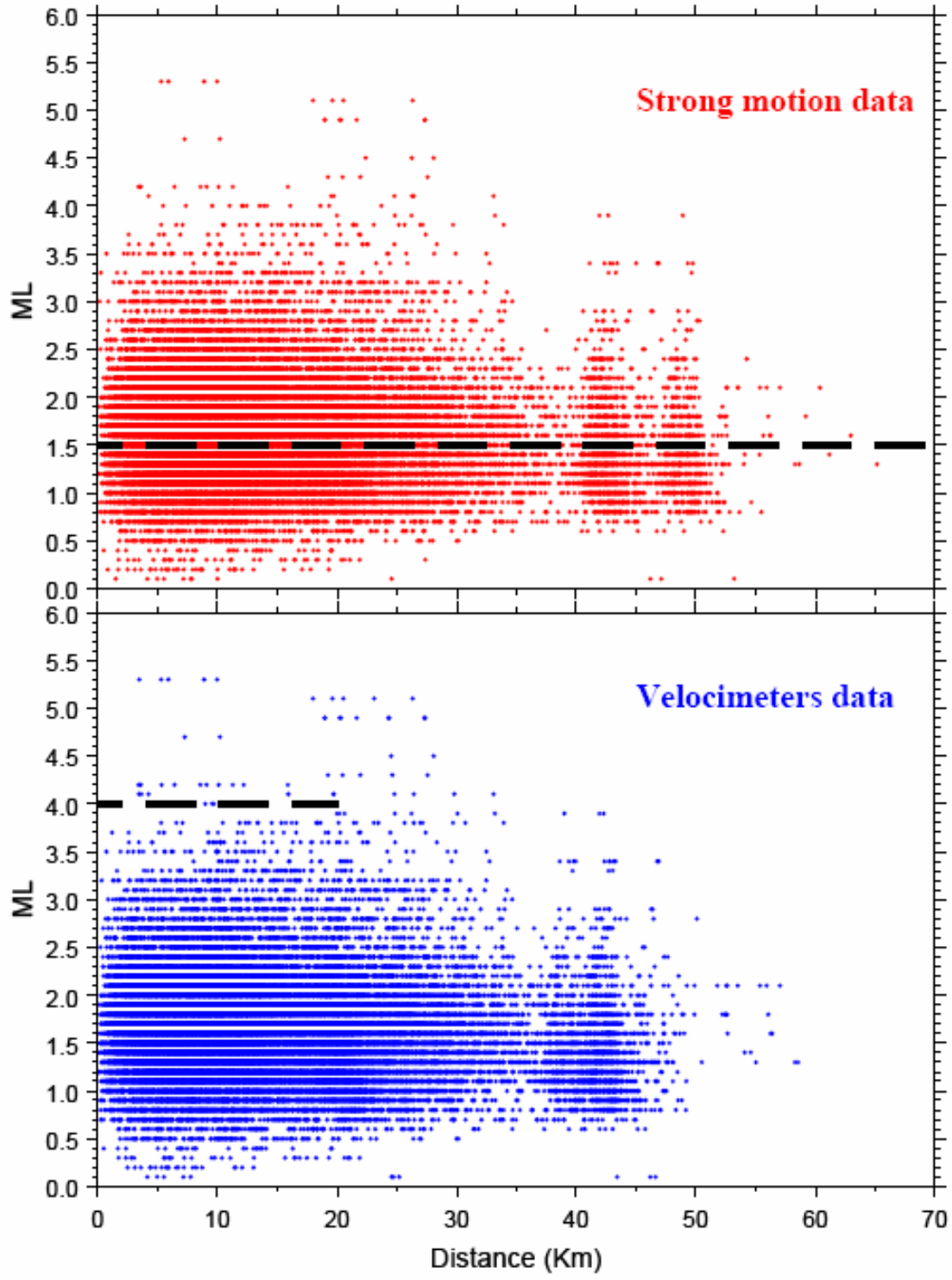

Strong motion data
Velocimeters data
ML
ML
Distance (Km)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
0
10
20
30
40
50
60
70

FIG.5

# STATION	M01a	M01v	M02a	M02v	M03a	M03v	M04a	M04v	M05a	M05v	M06a	M06v	M07a	M07v	M08a	M08v	M09a	M09v	M10a	M10v	M11a	M11v	M12a	M12v	M13a	M13v	M14a	M14v
# COMPONENT	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ
20090407092628	+++	+++	+++	+++	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
20090407174737	+++	+++	+++	+++	+++	+++	...	+++	+++	+++	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
20090407213429	+++	+++	+++	+++	+++	+++	...	+++	+++	+++	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
20090408225650	+++	+++	+++	+++	+++	+++	...	+++	+++	+++	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
20090409005259	+++	+++	+++	+++	+++	+++	...	+++	+++	+++	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
20090409031452	+++	+++	+++	+++	+++	+++	...	+++	+++	+++	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
20090409043244	+++	+++	+++	+++	+++	+++	...	+++	+++	+++	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
20090409193816	+++	+++	+++	+++	+++	+++	...	+++	+++	+++	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
20090413211424	+++	+++	+++	+++	...	...	...	+++	+++	+++	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
20090414201727	+++	+++	+++	+++	...	...	...	+++	+++	+++	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
20090423151408	+++	+++	+++	+++	...	...	...	+++	+++	+++	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
20090423214900	+++	+++	+++	+++	...	...	...	+++	+++	+++	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
20090622205840	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+++
20090703110307	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
20090712083851	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

...

M15a	M15v	M16a	M16v	M17a	M17v	M18a	M18v	M19a	M19v	M20a	M20v	M21a	M21v	M22a	M22v	M23a	M23v	M24a	M24v	M25a	M25v	M26a	M26v	M27a	M27v	M28a	M28v	M29a	M29v	M30a	M30v
NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ	NEZ
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	+++	...	+++	...	...	...	+++	+++	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+++	+++	...	+++	...	+++	+++	...	+++	...	...	+++	+++	+++	...	+++
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+++	+++	...	+++	...	+++	+++	...	+++	...	...	+++	+++	+++	...	+++

...

FIG.6

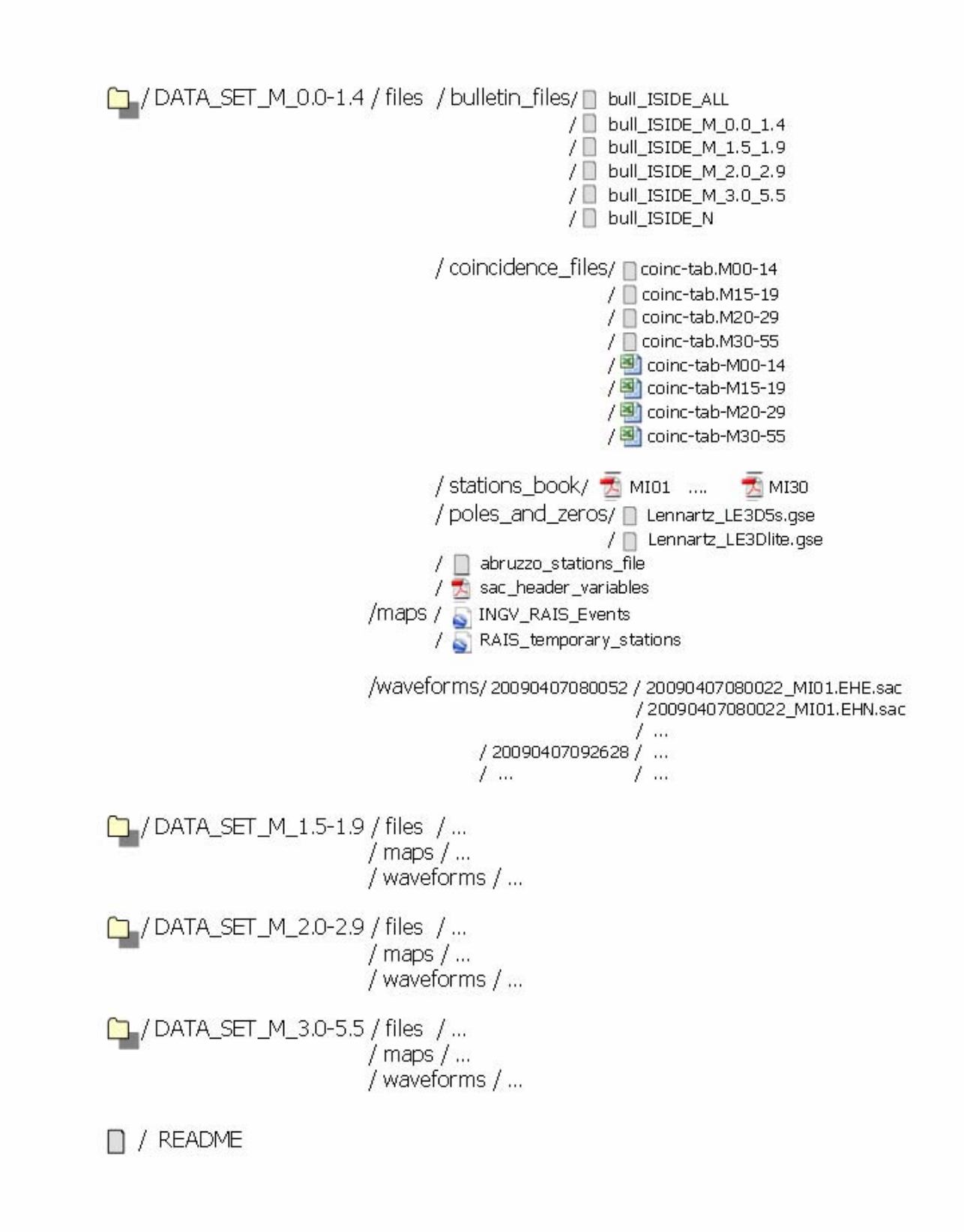

/ DATA_SET_M_0.0-1.4 / files / bulletin_files/ bull_ISIDE_ALL
/ bull_ISIDE_M_0.0_1.4
/ bull_ISIDE_M_1.5_1.9
/ bull_ISIDE_M_2.0_2.9
/ bull_ISIDE_M_3.0_5.5
/ bull_ISIDE_N
/ coincidence_files/ coinc-tab.M00-14
/ coinc-tab.M15-19
/ coinc-tab.M20-29
/ coinc-tab.M30-55
/ coinc-tab-M00-14
/ coinc-tab-M15-19
/ coinc-tab-M20-29
/ coinc-tab-M30-55
/ stations_book/ MI01 .... MI30
/ poles_and_zeros/ Lennartz_LE3D5s.gse
/ Lennartz_LE3Dlite.gse
/ abruzzo_stations_file
/ sac_header_variables
/maps / INGV_RAIS_Events
/ RAIS_temporary_stations
/waveforms/ 20090407080052 / 20090407080022_MI01.EHE.sac
/ 20090407080022_MI01.EHN.sac
/ ...
/ 20090407092628 / ...
/ ... / ...
/ DATA_SET_M_1.5-1.9 / files / ...
/ maps / ...
/ waveforms / ...
/ DATA_SET_M_2.0-2.9 / files / ...
/ maps / ...
/ waveforms / ...
/ DATA_SET_M_3.0-5.5 / files / ...
/ maps / ...
/ waveforms / ...
/ README

FIG.7

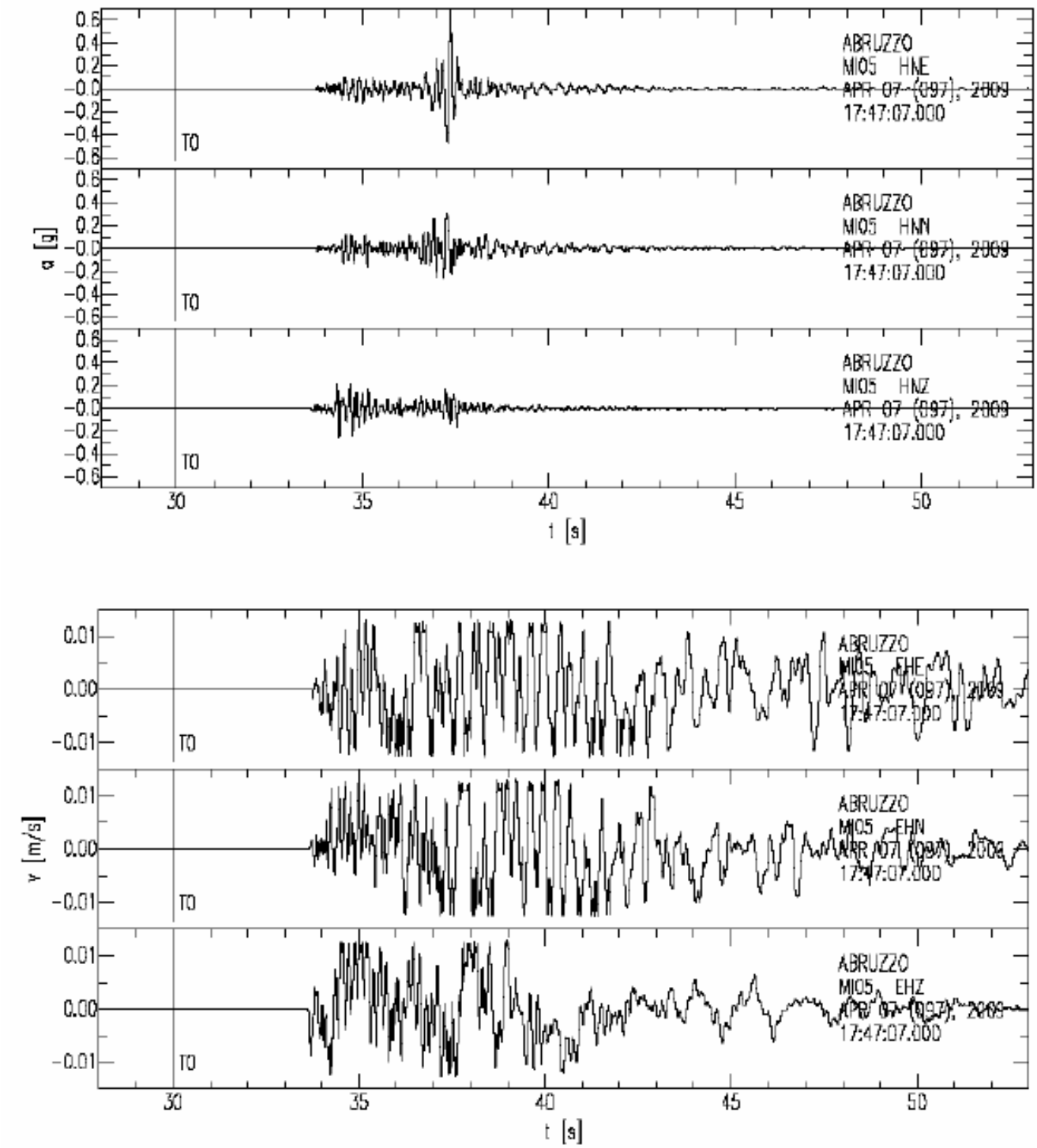

ABRUZZO
MIO5 HNE
APR 07 (097), 2009
17:47:07.000
ABRUZZO
MIO5 HNN
APR 07 (097), 2009
17:47:07.000
ABRUZZO
MIO5 HNZ
APR 07 (097), 2009
17:47:07.000
a [g]
T0
t [s]
ABRUZZO
MIO5 EHE
APR 07 (097), 2009
17:47:07.000
ABRUZZO
MIO5 EHN
APR 07 (097), 2009
17:47:07.000
ABRUZZO
MIO5 EHZ
APR 07 (097), 2009
17:47:07.000
v [m/s]
T0
t [s]

FIG. 8

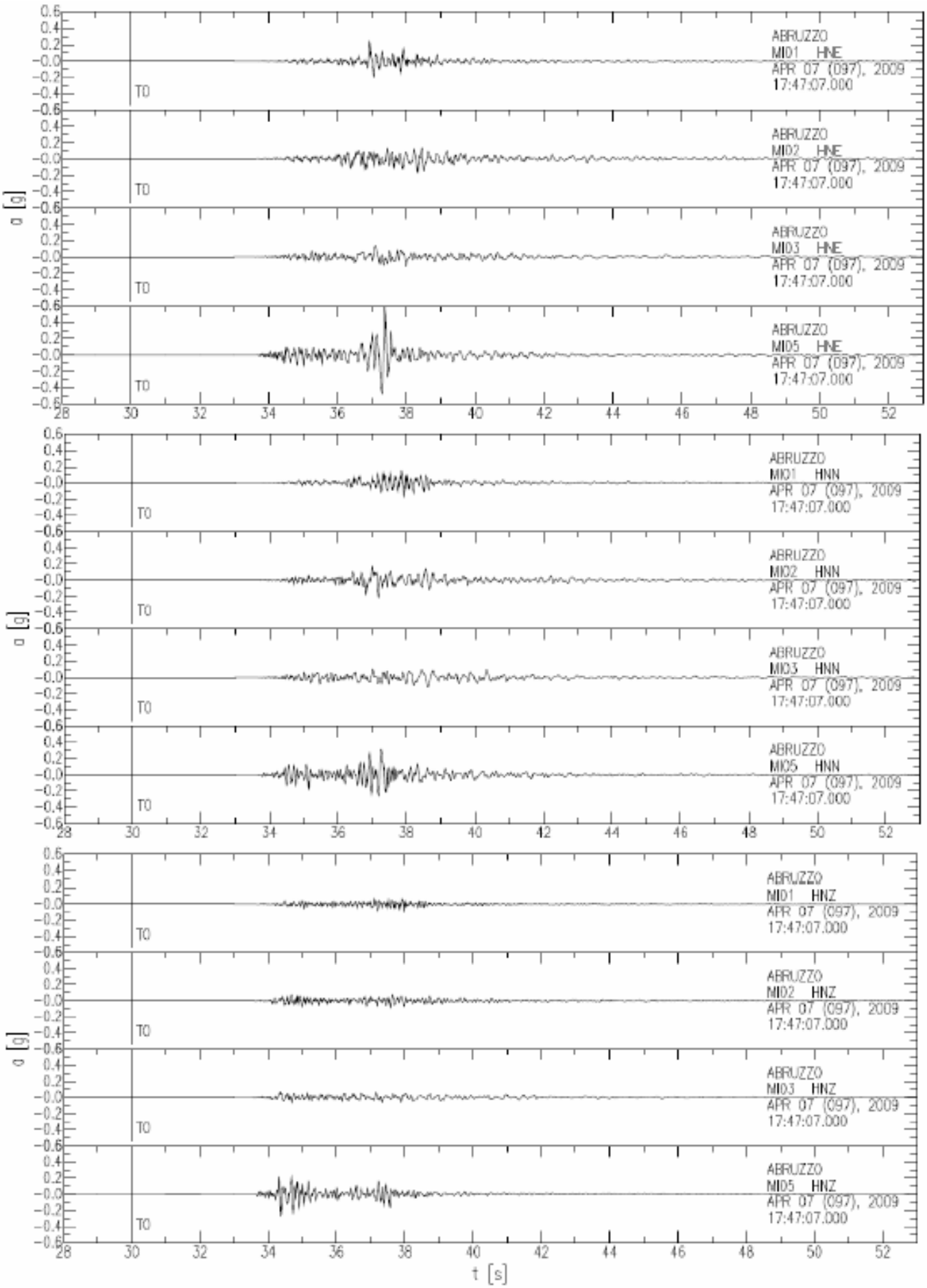
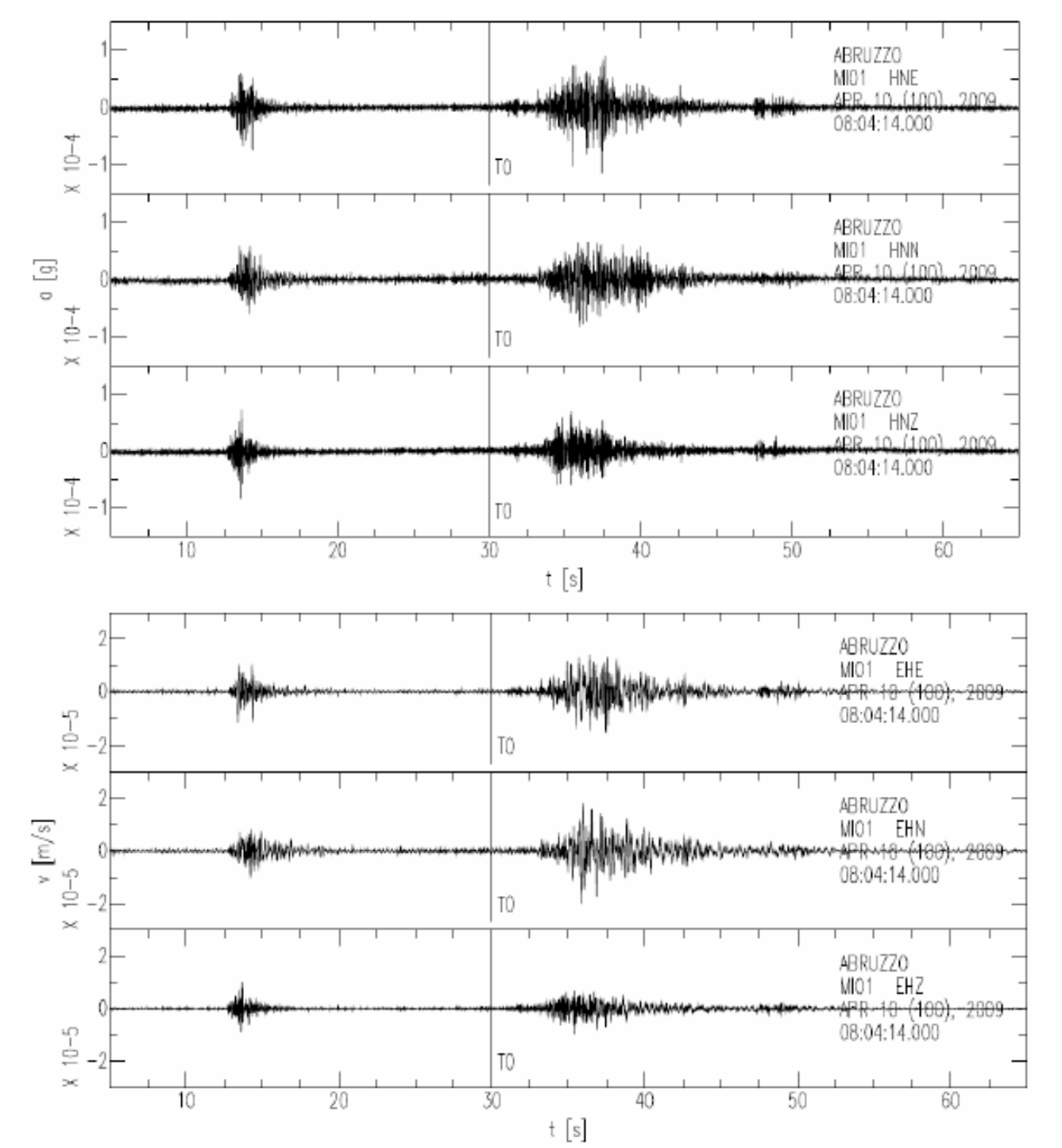

ABRUZZO
MI01 HNE
APR 07 (097), 2009
17:47:07.000
ABRUZZO
MI02 HNE
APR 07 (097), 2009
17:47:07.000
ABRUZZO
MI03 HNE
APR 07 (097), 2009
17:47:07.000
ABRUZZO
MI05 HNE
APR 07 (097), 2009
17:47:07.000
ABRUZZO
MI01 HNN
APR 07 (097), 2009
17:47:07.000
ABRUZZO
MI02 HNN
APR 07 (097), 2009
17:47:07.000
ABRUZZO
MI03 HNN
APR 07 (097), 2009
17:47:07.000
ABRUZZO
MI05 HNN
APR 07 (097), 2009
17:47:07.000
ABRUZZO
MI01 HNZ
APR 07 (097), 2009
17:47:07.000
ABRUZZO
MI02 HNZ
APR 07 (097), 2009
17:47:07.000
ABRUZZO
MI03 HNZ
APR 07 (097), 2009
17:47:07.000
ABRUZZO
MI05 HNZ
APR 07 (097), 2009
17:47:07.000
T0
a [g]
t [s]

FIG. 9


ABRUZZO
MI01 HNE
APR 10 (100), 2009
08:04:14.000
ABRUZZO
MI01 HNN
APR 10 (100), 2009
08:04:14.000
ABRUZZO
MI01 HNZ
APR 10 (100), 2009
08:04:14.000
a [g]
X 10-4
T0
t [s]
ABRUZZO
MI01 EHE
APR 10 (100), 2009
08:04:14.000
ABRUZZO
MI01 EHN
APR 10 (100), 2009
08:04:14.000
ABRUZZO
MI01 EHZ
APR 10 (100), 2009
08:04:14.000
v [m/s]
X 10-5
T0
t [s]