RU S3/4 INGV Milano-Pavia: Implementation of the ShakeMap® System at the Rais

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INGV Istituto Nazionale di Geofisica e Vulcanologia Project DPC-S3 (2007-2009)
Fast evaluation of parameters and effects of strong earthquakes in Italy and in the Mediterranean

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This work summarizes the activities performed by the INGV MI-PV research unit (RU4) with reference to the planned work-packages (WP). In order to assure the availability of the highest number of strong-motion data and with the aim to provide reliable real-time ground shaking evaluations, the activity was devoted to update the data acquisition system of the **RAIS** (Strong Motion Network in Northern Italy; in italian: **R**ete **A**ccelerometrica in **I**talia **S**ettentrionale) network.
At present, 7 out of the 21 stations of the network were updated by replacing the original acquisition system (with modem GSM transmission system) with a **real-time acquisition system**, based on digital recorders with TCP/IP or Wi-Fi link. All stations are equipped with Kinemetrics Episensor accelerometers. For the management of the real time stations the SEEDlink and Earthworm packages were adopted and the MiniSEED format was introduced for real-time data exchange **(WP1.1)**.

The data dissemination was achieved by making available on the website (http://rais.mi.ingv.it) the computed strong motion parameters, together with the amplification functions, for each recording station. Acceleration data are also made available on the Italian Accelerometric Archive (http://itaca.mi.ingv.it) **(WP1.4)**.

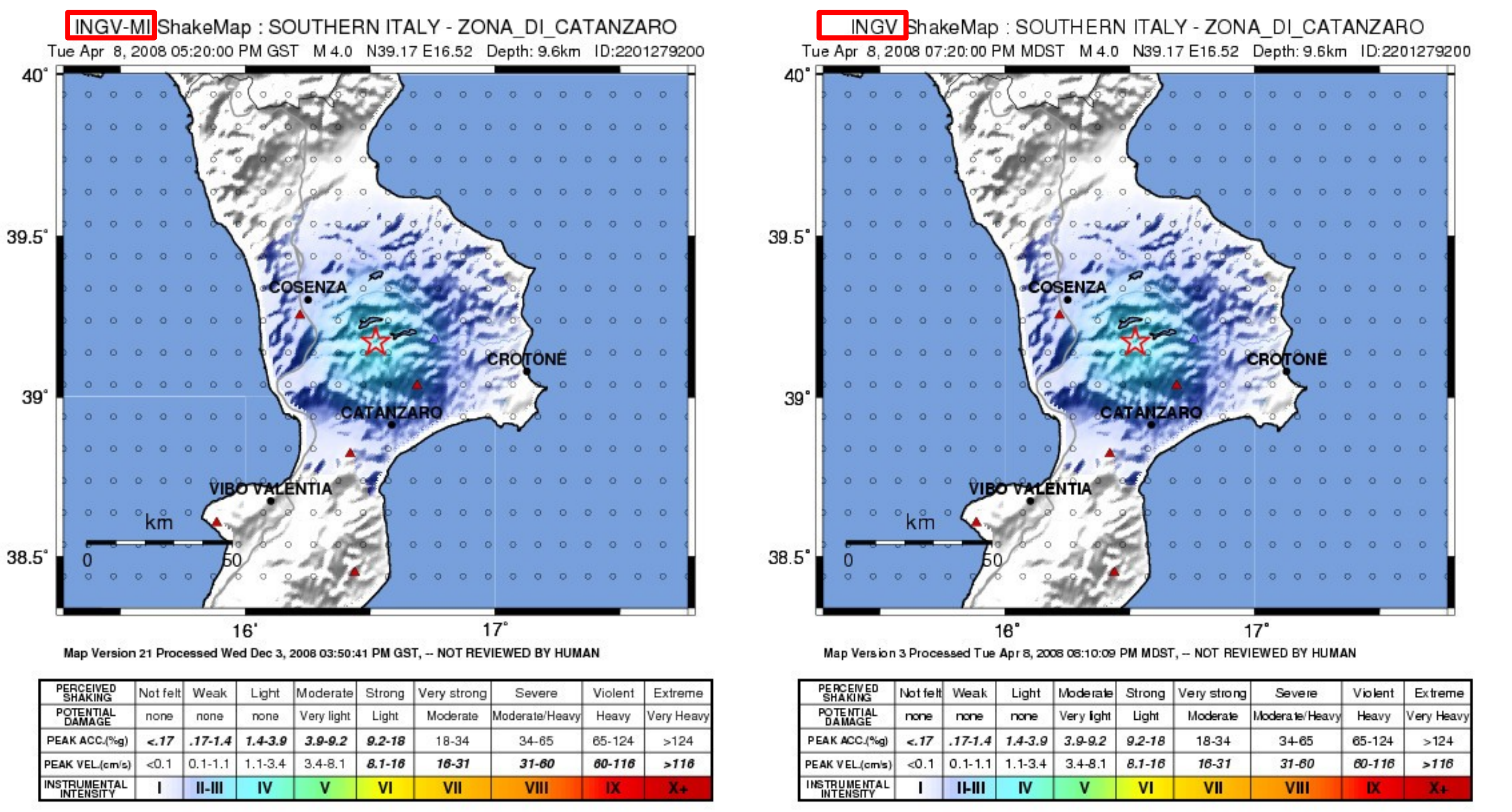
The ShakeMap program was successfully installed. Ground shaking maps of 3 events recorded by the National Seismic Network and used as reference solutions, were accurately reproduced. Moreover, in order to verify the quality of the procedures used for the Peak Ground Motion (PGM) evaluation, several strong motion parameters were calculated starting from the input waveforms and then successfully compared with the reference values **(WP2.1)**.

Four GMPEs were used to predict the ground shaking of December 23, 2008, Ml 5.1 and Ml 4.7 Parma earthquakes and to compare predicted PGAs with the peak values recorded by 33 stations of the RAN and RAIS networks. Comparisons were made considering both national and regional relationships. In addition, studies on high frequency attenuation of S-waves in Eastern Alps and effects of Moho reflection (SmS) in the Po Plain has been performed **(WP3.4, see also Poster S3-9: Gentili and Franceschina; Oral presentation and Poster Strong Ground Motion 2: Bragato et al., "Effects of Moho reflections (SmS) in the Po plain and implications for ground motion prediction in northern Italy")**.

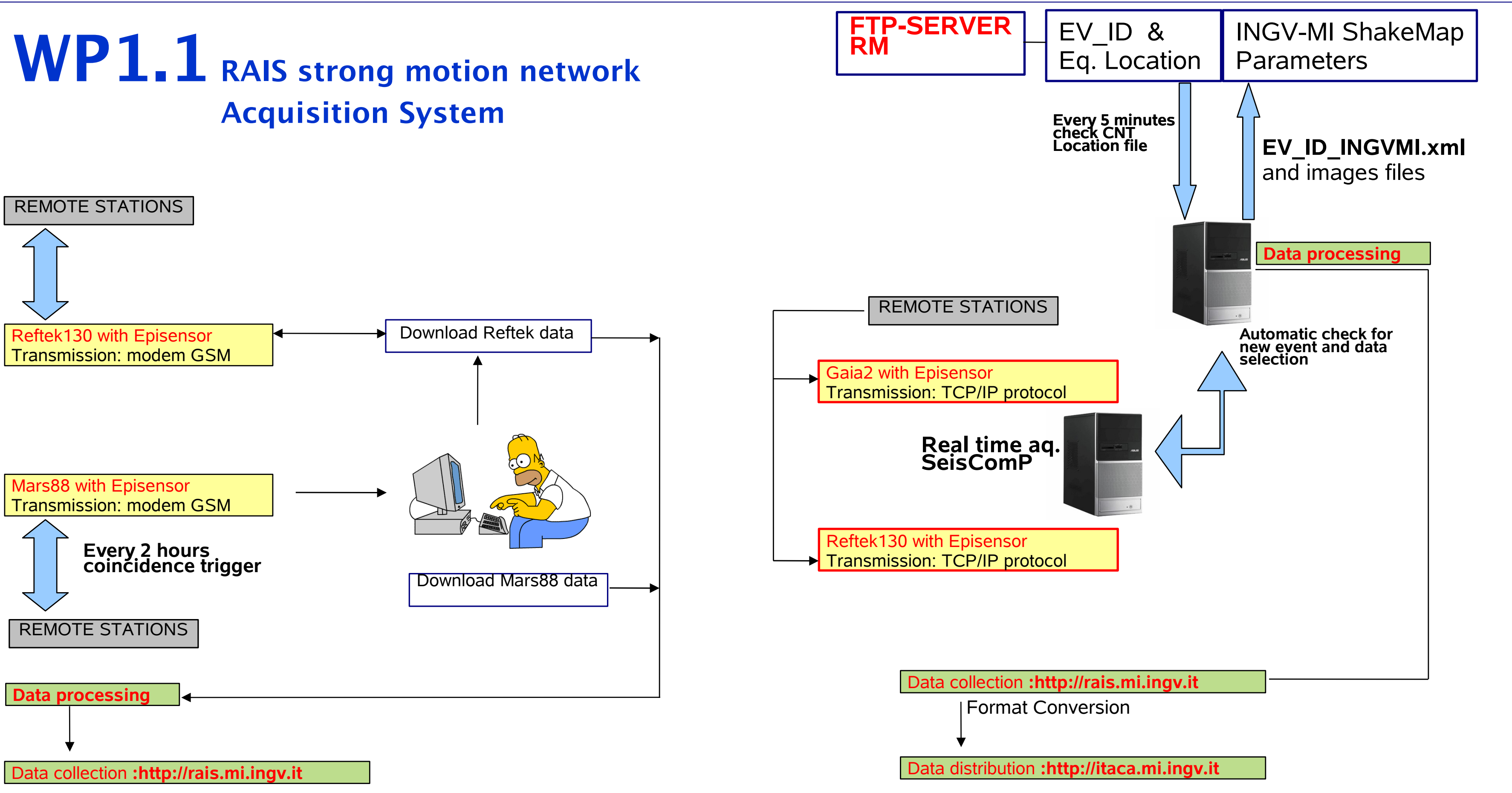
Part of the RU4 activity was devoted to investigate the high-frequency methodologies suitable to simulate synthetic seismograms to be used in place of GMPE within the ShakeMap methodology. The June 14, 2008, M_w=6.9, Miyagi (Japan) earthquake was recorded by a large number of stations and produced a "reference ShakeMap" almost totally relying on the recorded ground motions. Starting from another, deliberately ill-constrained ShakeMap and considering the information on the finite-fault characteristic of this earthquake, ground-motion simulations were performed with different stochastic techniques. Ground motion parameters were calculated for a dense configuration of sites in order to compare these "synthetic ShakeMaps" with the "reference ShakeMap" **(WP 4.3, see Poster S3-1: Ameri et al., "ShakeMap: accounting for finite fault though synthetic waveforms")**.

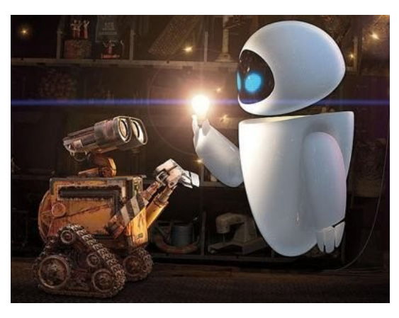
RAIS Strong motion Network: a typical installation.
Oppeano (OPPE) strong motion station equipped with a router for real-time data transmission, 24 bits recording system and Kinemetric Episensor FBA ES-T (Dyamic Range 155 dB+).

WP2.1 Test of the ShakMap program.

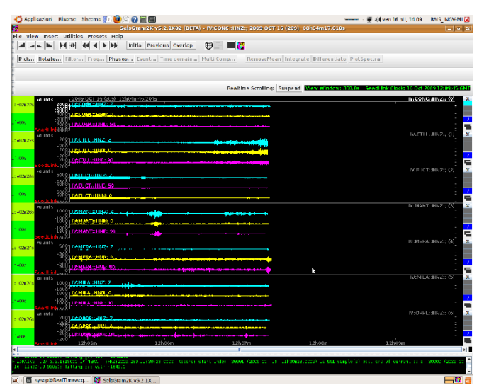


WP1.1 RAIS strong motion network
Acquisition System





Looking towards the future

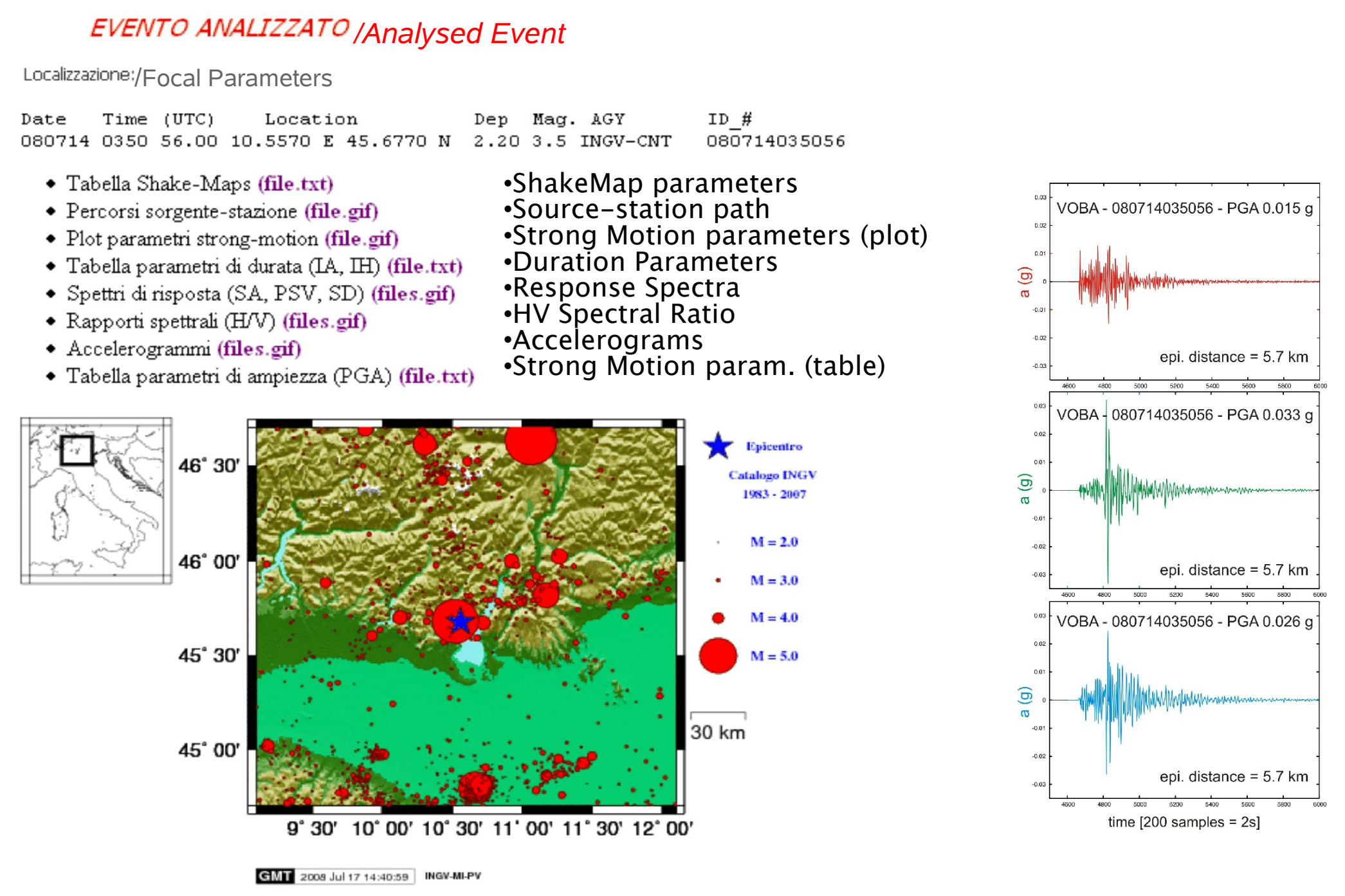


The stations cover in particular the area shocked by the 24 November 2004, Ml 5.2 Salò earthquake. At the starting of the project the stations were equipped with 24 bits sensors (*Kinemetrics Episensor*) coupled with both 20 bits (*Lennartz Mars88/MC*) and 24 bits (*Reftek 130*) digital recorders. Data were transmitted via modem/gsm for all the stations. The gsm data transmission do not allow a real-time determinations of the parameters of interest. In those days the availability of digital strong motion data represent the main scope, even if with a lapse time of the order of hours/days. **Today, the real time is more and more relevant** and a target for the S3 Project is to assure the availability of the highest numbers of experimental data with the aim to provide reliable shaking evaluations in real-time. The Mars88/MC recorders are not suitable for real time transmission and then we start a phase of replacement with well-tried digitizer working with both GSM and TCP-IP connection. It is interesting to note that it causes a **complete remake of the seismological signal chain and data management**: the previous setting was based on the automatic trigger of the Mars88 system.
At present 7 stations has been connected to the acquisition centre of our Department in real-time, using a TCP-IP link. For these stations we used also the *GAIA2* digital recorders (produced by the laboratory of CNT-INGV). In particular for this project, for the management of the real time stations we adopt in our Department the SEEDlink software. The format of the data was uploaded introducing the MiniSEED format. We use the SEEDlink server based on TCP/IP protocol for real time data communication and SEEDlink clients for monitor plotting and disk recording. The Earthworm system has been also introduced with the use of *Swarm* software for the data presentation. For real time data acquisition, we develop a procedure for event detection using the location given by the "Sala Sismica" of CNT-Rome. We consider the locations as warning signals for data acquisition of the RAIS and of consequence to transform the flux of information coming from Milan in a fully automatic system. In particular, every 5 minutes we download the file containing the list of locations (revised by the Seismologist which is in charge for the seismic surveillance activity in Rome). We check if there is a new event, and we compare the theoretic signal level, in a fixed frequency band, with the average noise levels measured at each site. If a fixed threshold value is exceeded for almost 3 station, the **CNT event ID** is then memorized and the procedure for the download at the RAIS stations is starting. When the waveforms are available in the workstation the analysis procedure is able to produce all results in a few minutes.

WP1.1 RAIS strong motion network
Analysis System

An example for the 14th July 2008, Ml 3.5 earthquake

In the web site for each recorded event there is a page that resume all results coming from the automatic procedure of seismic analysis implemented at INGV MI-PV. In this panel we show the accelerograms and specral ratios (EHVSR, calculated considering both 5s and 10s of the S phase) for the VOBA station. Plot for PGA and duration parameters and Table with PGA, PGV and SA (0.3s, 1.0s and 3.0s) are also reported.



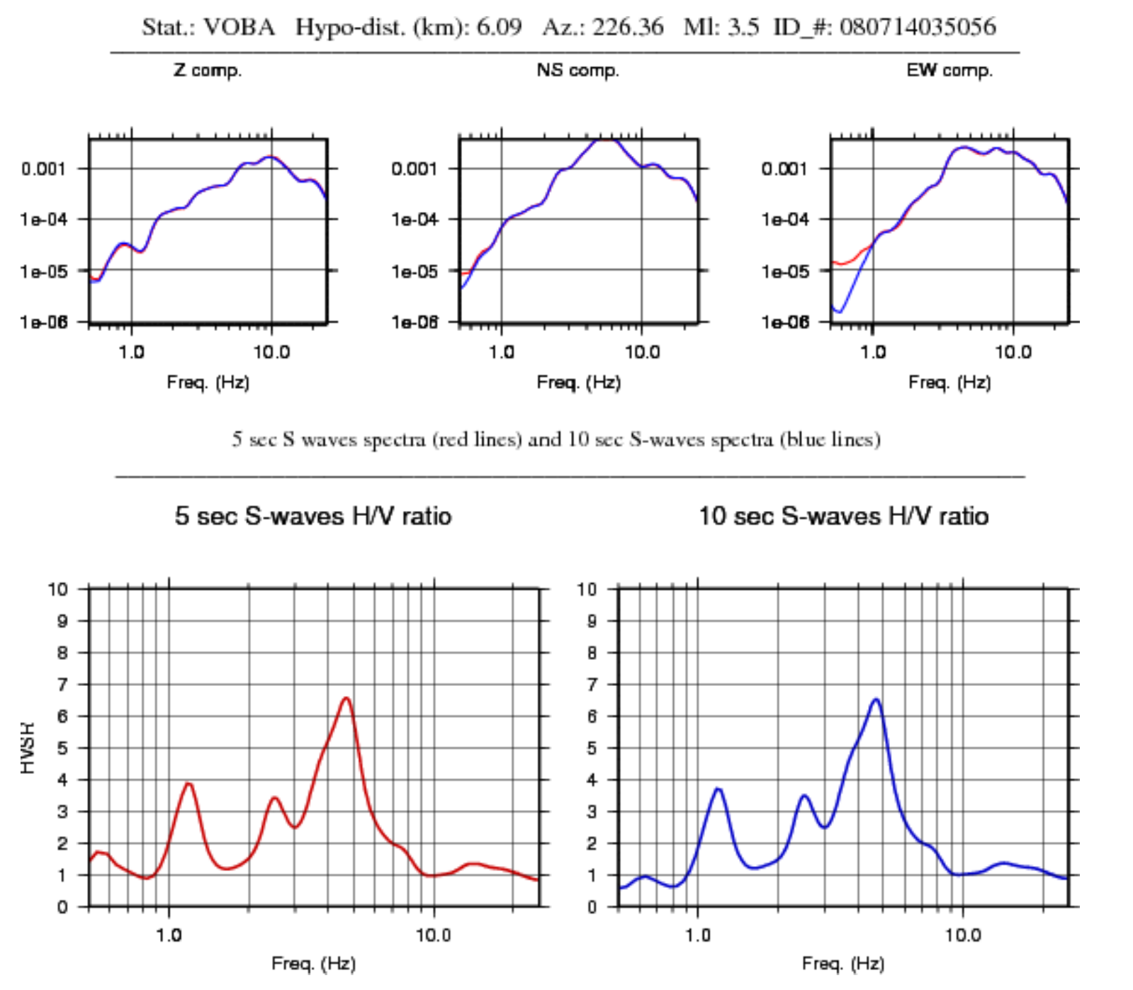
EVENTO ANALIZZATO /Analysed Event

Localizzazione:/Focal Parameters

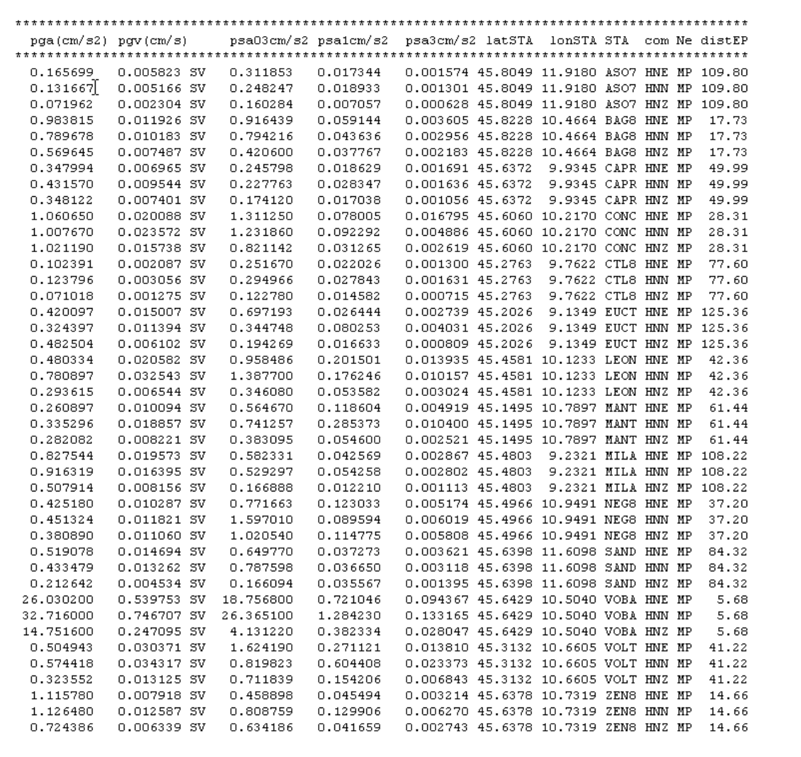
```
Date    Time (UTC)    Location              Dep  Mag. AGY       ID_#
080714  0350 56.00 10.5570 E 45.6770 N      2.20 3.5 INGV-CNT   080714035056
```

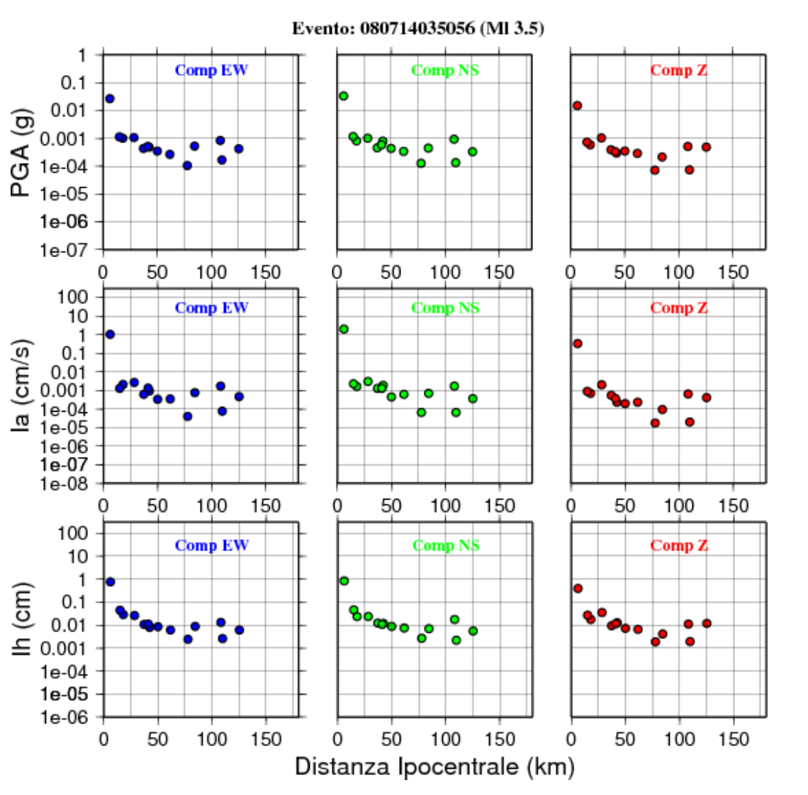
- Tabella Shake-Maps (file.txt)
- Percorsi sorgente-stazione (file.gif)
- Plot parametri strong-motion (file.gif)
- Tabella parametri di durata (IA, IH) (file.txt)
- Spettri di risposta (SA, PSV, SD) (files.gif)
- Rapporti spettrali (H/V) (files.gif)
- Accelerogrammi (files.gif)
- Tabella parametri di ampiezza (PGA) (file.txt)

•ShakeMap parameters
•Source-station path
•Strong Motion parameters (plot)
•Duration Parameters
•Response Spectra
•HV Spectral Ratio
•Accelerograms
•Strong Motion param. (table)



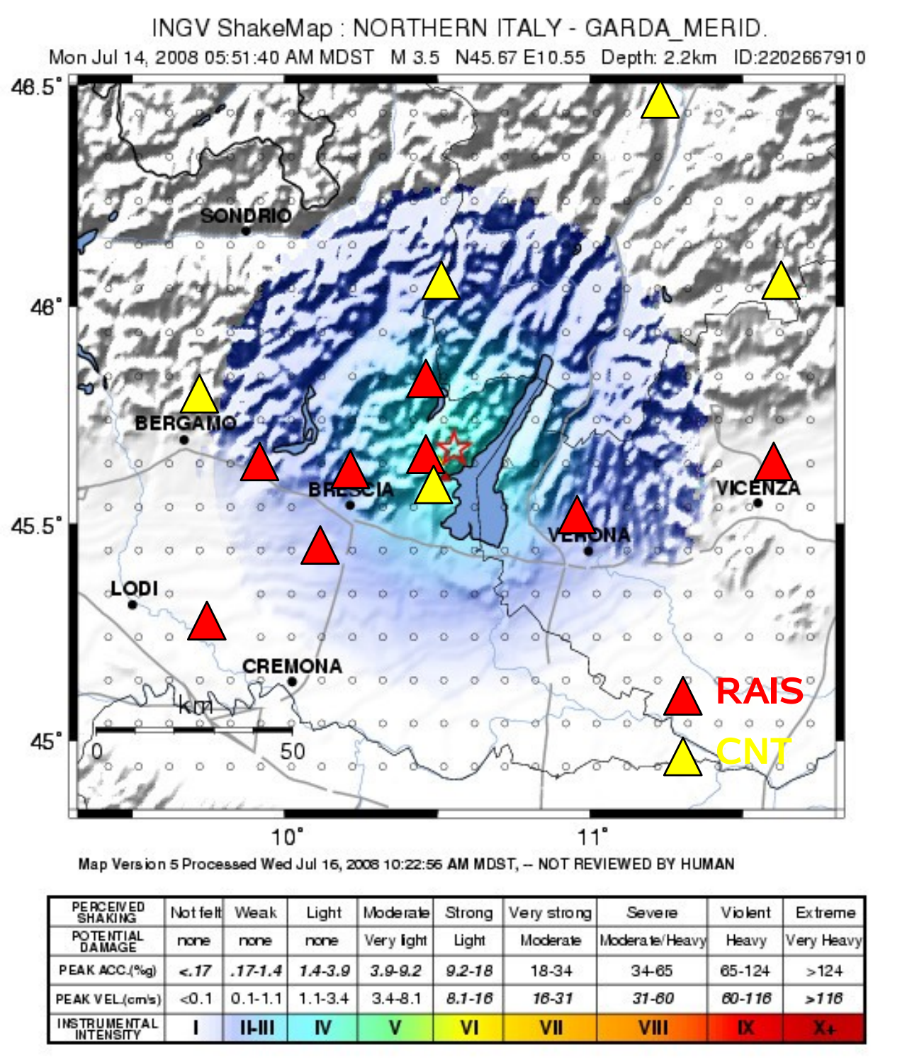
RAIS Strong motion Network: Vobarno (VOBA) station analysis

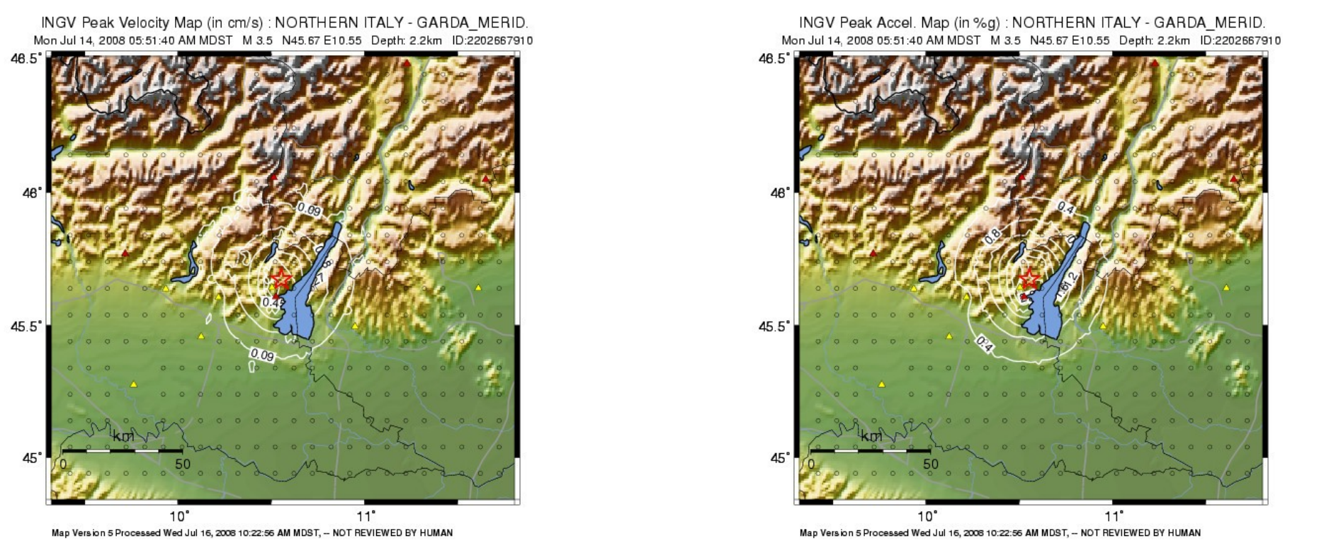




DATA DISSEMINATION

On the site (http://rais.mi.ingv.it) it is possible to find for each recorded event, the focal parameter (coming from the official site of INGV CNT) and the tables containing strong motion amplitude (PGA, PGV), spectral parameters (SA, PSV, PSD), integral parameters (Arias and Housner intensities) and amplification functions for each station.
The data recorded by the RAIS network are converted in the format of the Italian accelerometric database (ITACA) and are also distributed on that website http://itaca.mi.ingv.it).

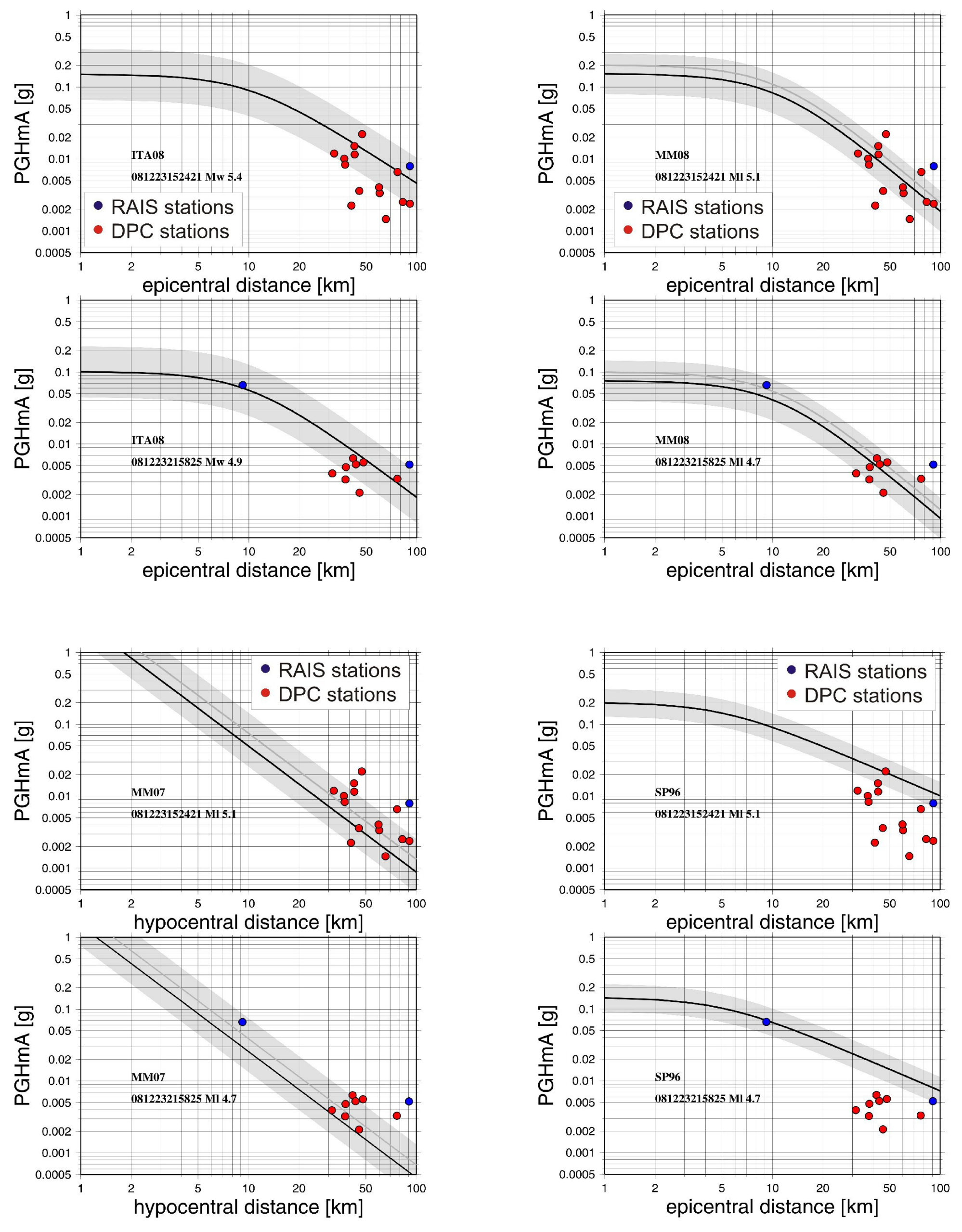




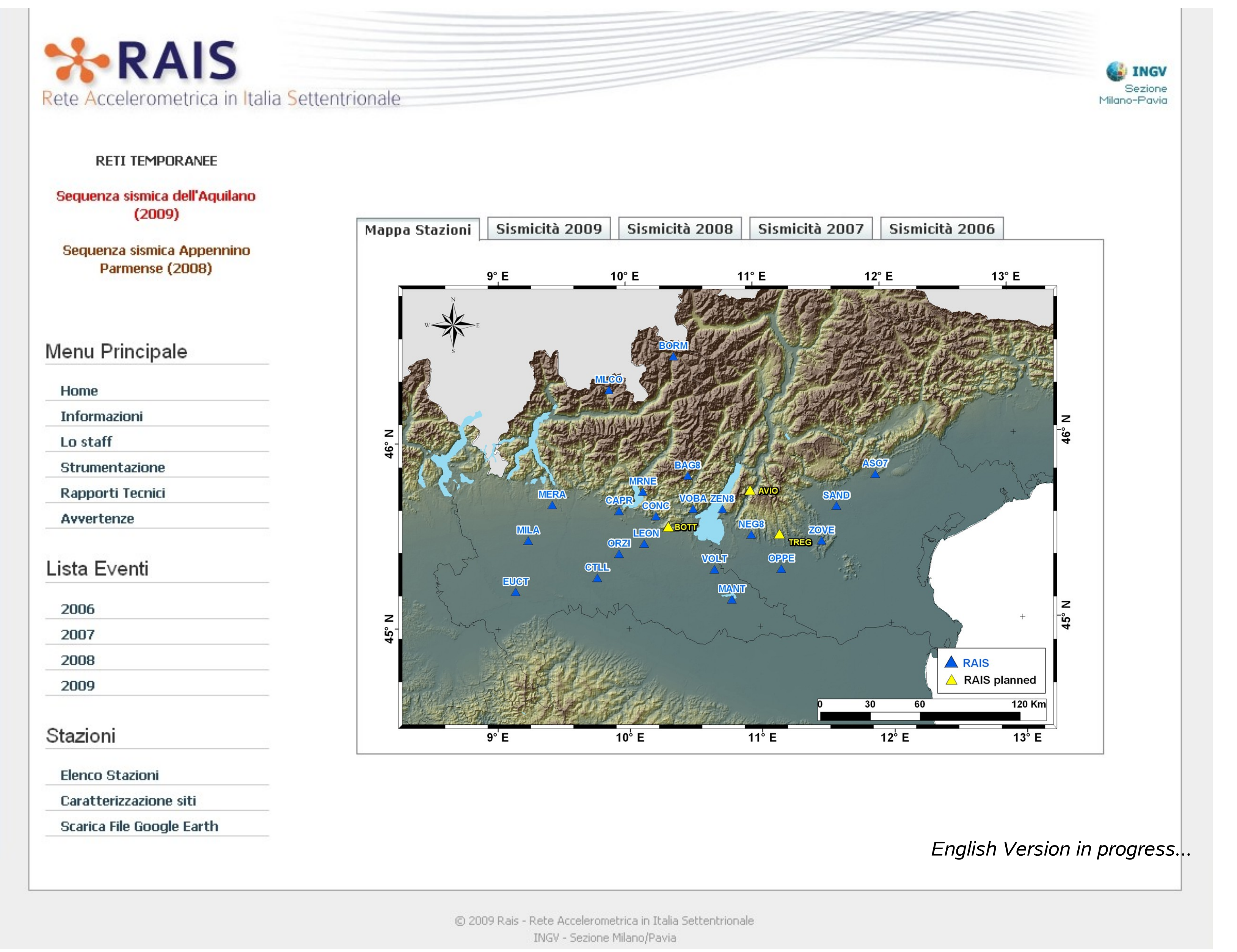
WP3.4

Comparisons among several empirical Ground Motion Prediction Equations used to predict the ground shaking of 23 December 2008, Ml 5.1 (Mw 5.4) and 4.7 (Mw 4.9) Parma earthquakes are presented. Both the mainshock (origin time 15:24:21 GMT) and the aftershock (origin time 21:58:25 GMT) have a hypocentral depth larger than 20 km, and a reverse focal mechanism. The mainshock was recorded by 33 stations of the RAN (http://itaca.mi.ingv.it) and RAIS (http://rais.mi.ingv.it) networks, in the range of epicentral distance between 32.2 and 216.9 km. Since most of these stations have been installed after 2004, they were not considered in the development of the presented GMPEs. The aftershock was recorded by 26 stations, in the distance range from 9.2 and 216.7 km. The closest recording is related to a temporary station, installed by INGV MI-PV after the mainshock occurrence. The examples are reported in terms of PGHA (horizontal Peak Ground Acceleration). The comparison were made considering both GMPEs calibrated at national scale (ITA08 and SP96) and GMPEs calibrated at regional scale (MM08 and MM07). As possible to state from figures the main discrepancies (overestimation for large distances) are related to the SP96 relation (Sabetta and Pugliese, 1996) calibrated considering earthquakes with Ml or Mw spanning from 4.6 to 6.9. Moreover this relation not takes into account (in the attenuation term of the functional form) the magnitude-dependent decay rate. At the same time the MM07 (Massa et al., 2007; not applicable for distances below 5 km) relation, developped considering only weak motions recorded in North Central Italy underestimates the observed data. A good agreement is instead observed both considering ITA08 (Bindi et al., 2009) and MM08 (Massa et al., 2008): this two relations, even if were developped considering respectively data at national scale (in the first case) and related to the whole North Italy (in the second case), are characterized by very comparable values of independent variables (magnitude and distance).

ITA08: Bindi, D., L. Luzi, M. Massa and F. Pacor (2009), Horizontal and vertical ground motion prediction equations derived from the Italian Accelerometric Archive (ITACA), Bull. Earth. Eng., in press
MM07: Massa M., S. Marzorati, E. D'Alema, D. Di Giacomo and P. Augliera (2007) Site Classification Assessment for Estimating Empirical Attenuation Relationships for Central-Northern Italy Earthquakes, Journal of Earthquake Engineering, 11, 943-967.
MM08: Massa, M., P. Morasca, L. Moratto, S. Marzorati, G. Costa and D. Spallarossa (2008) Empirical Ground-motion equation for northern Italy using weak- and strong-motion amplitudes, frequency content, and duration parameters. Bull. Seism. Soc. Am., 98,1319-1342.



WP1.4 Web Site http://rais.mi.ingv.it



RAIS
Rete Accelerometrica in Italia Settentrionale
INGV Sezione Milano-Pavia

RETI TEMPORANEE
Sequenza sismica dell'Aquilano (2009)
Sequenza sismica Appennino Parmense (2008)

Menu Principale
- Home
- Informazioni
- Lo staff
- Strumentazione
- Rapporti Tecnici
- Avvertenze

Lista Eventi
- 2006
- 2007
- 2008
- 2009

Stazioni
- Elenco Stazioni
- Caratterizzazione siti
- Scarica File Google Earth

English Version in progress...

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