UNIVERSITÀ
DEGLI STUDI
DI TRIESTE

Applied seismology

Introduction

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Course objectives and structure

The course is divided into several teaching units.

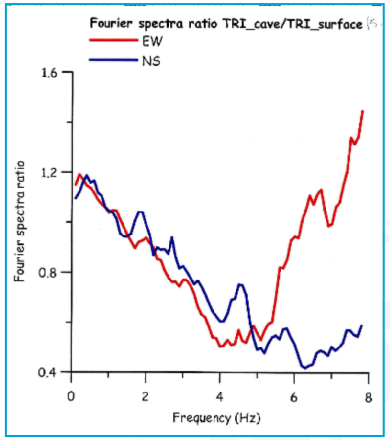
Specifically:

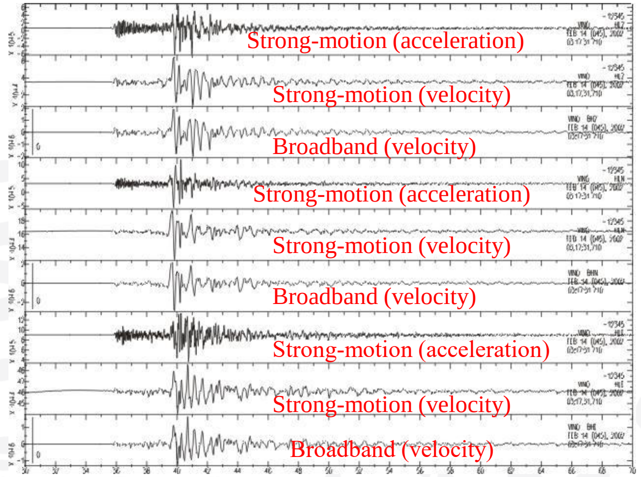
- Seismic source
- Seismic waves
- Seismological instrumentation
- Seismic monitoring,
- Seismic networks (short period, broadband, accelerometer)
- Seismic signal analysis (time and frequency domain analysis, Fourier transform, filtering)
- Localization of events
- Main characteristics of seismic motion
- Strong ground motion parameters (PGA, PGV, PGD, Arias and Housner intensities, PSA03, PSA10, PSA30).
- Natural and induced seismic activity monitoring (site effects, microtremors, H/V technique (HVSR) 1D and 2D site response
- Soil/structure interaction

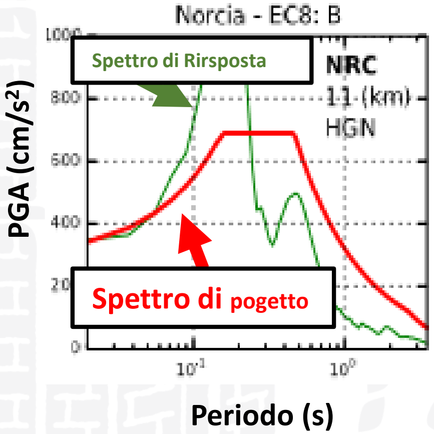
Final Examination

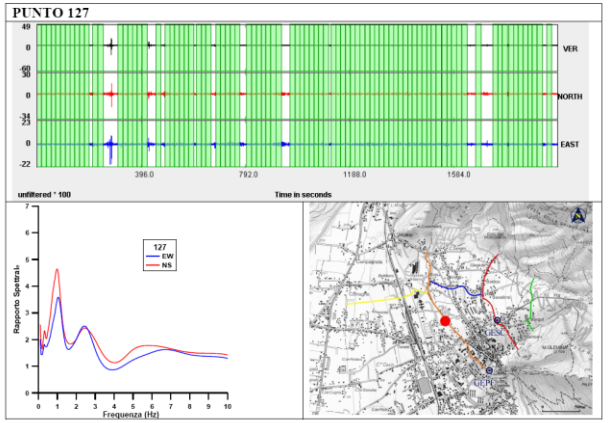
Individual practical test (Processing of an earthquake or microtremor signal) and oral. A recording of an earthquake or microtremors will be provided and asked to analyze it in the time and frequency domains using the techniques acquired during the course.

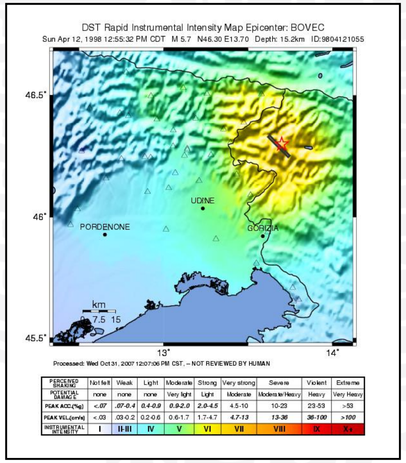
The practical part will be followed by an interview with questions on the topics covered in the course.











Teaching materials

New manual of seismological observatory practice - P Bormann - 2002

[New Manual of Seismological Observatory Practice – NMSOP](#)

Seismic Analysis Code Users Manual

https://ds.iris.edu/files/sac-manual/

Geopsy project (manual)

https://www.geopsy.org/documentation/geopsy/

Ricevimenti

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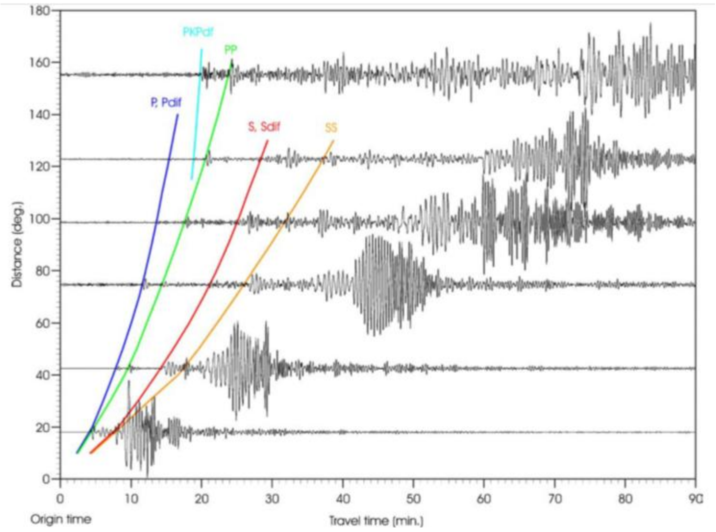
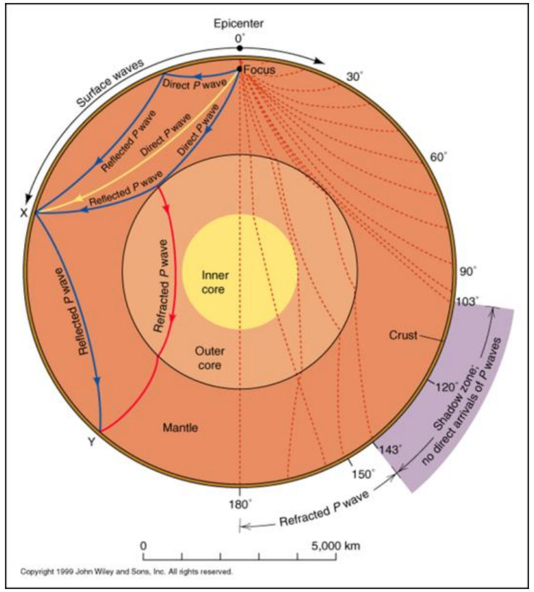
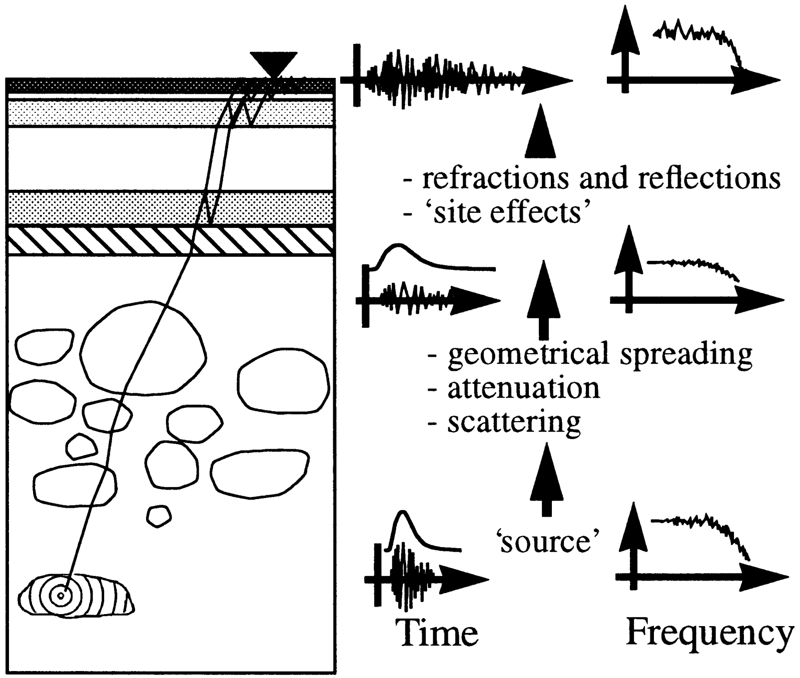
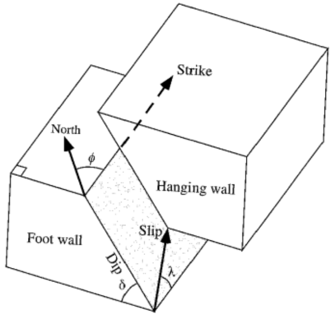
By appointment

Most of what we know today about the Earth's internal structure and physical properties, and thus about the internal forces that drive plate motions and cause major geologic features, has been derived from seismological data. Seismology continues to be a fundamental tool for investigating the kinematics and dynamics of geological processes at all scales. With continued advances in seismology we hope to better understand, predict and utilize our geological environment and its driving processes with their benefits and dangers to human society.

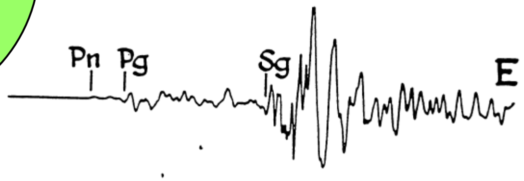








Seismic source → System or filter [Earth → Recorder] → Seismogram



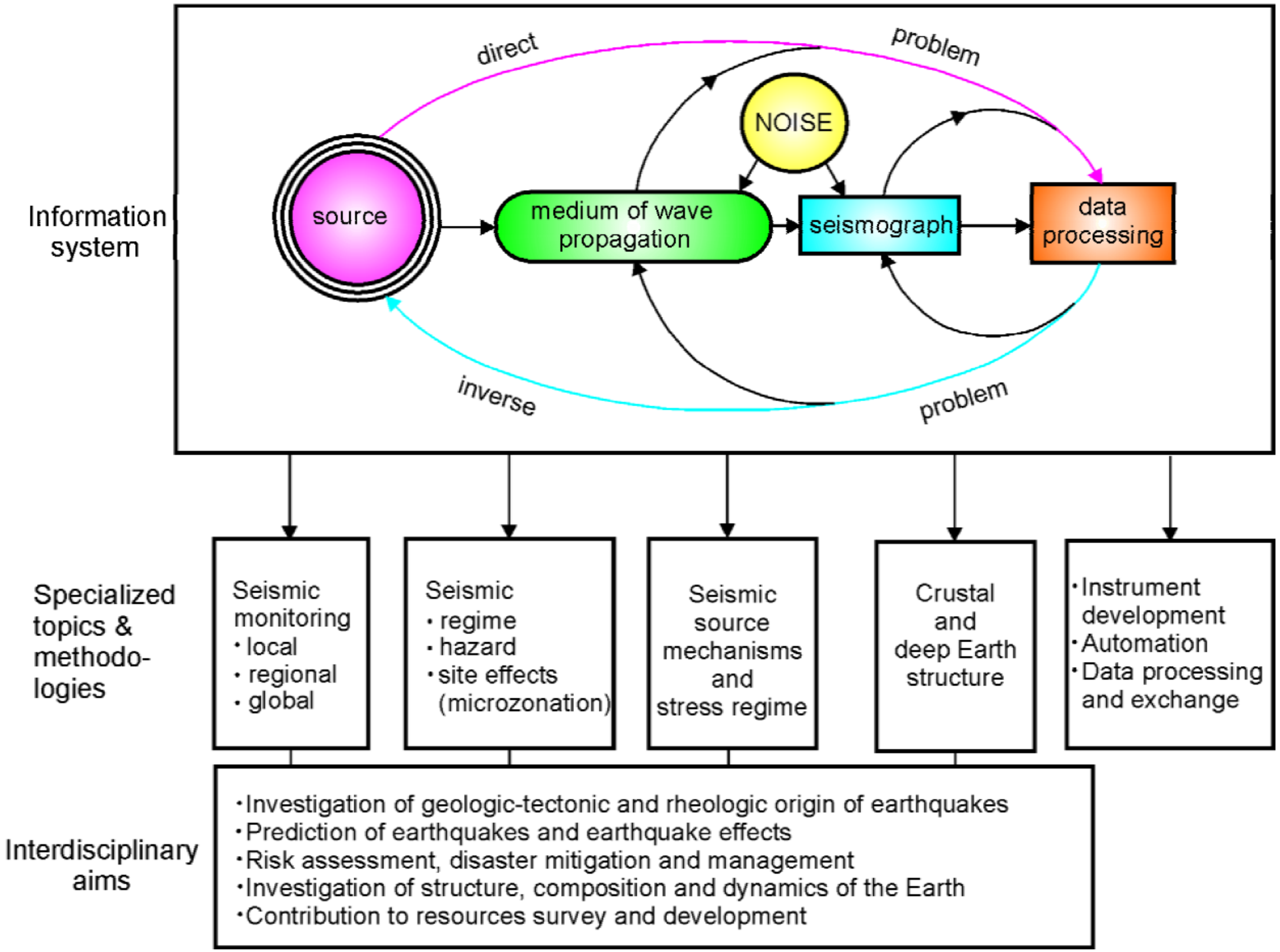
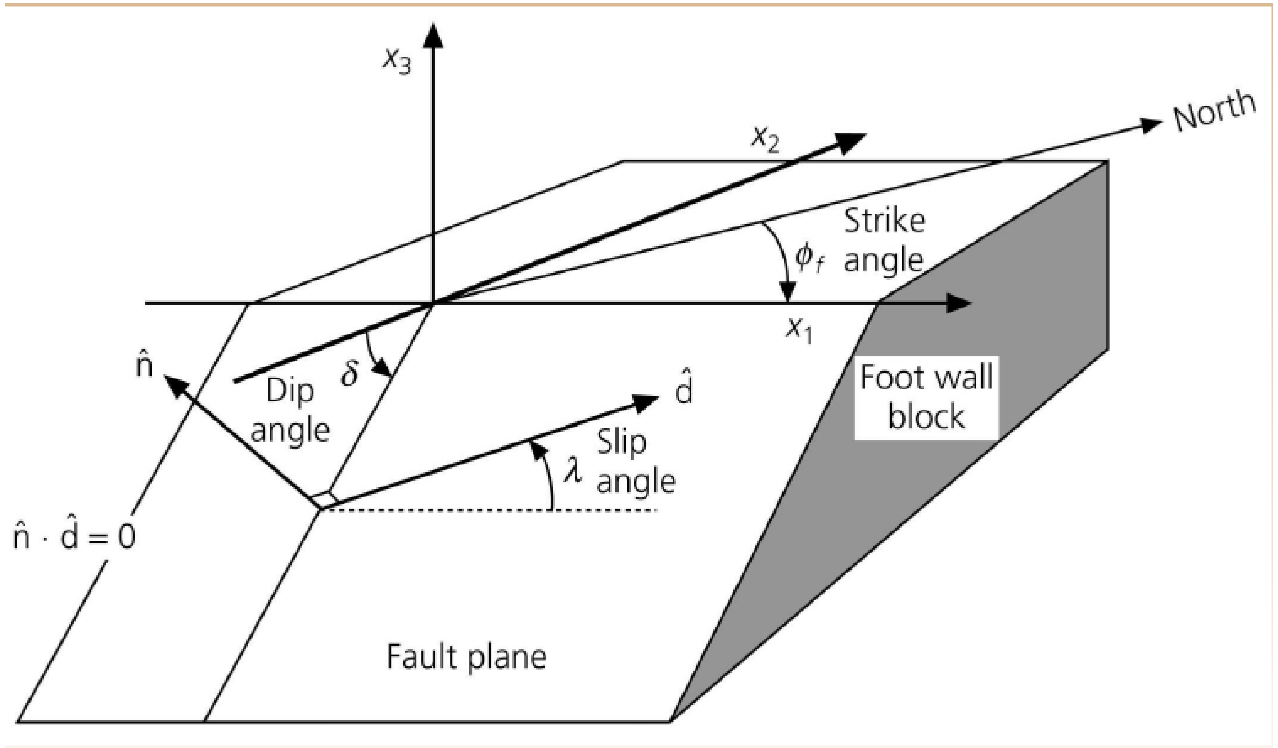


Diagram illustrating seismology as an analysis of a complex information system linked to a variety of specialized and interdisciplinary research tasks and applications.



To determine the focal mechanism we need three parameters:
Two for the fault plane and one for the slip direction:
Φ → the strike of the fault: Fault strike is the direction of a line created by the intersection of a fault plane and a horizontal surface, 0° to 360°, relative to North. Strike is always defined such that a fault dips to the right side of the trace when moving along the trace in the strike direction. The hanging-wall block of a fault is therefore always to the right, and the footwall block on the left. This is important because rake (which gives the slip direction) is defined as the movement of the hanging wall relative to the footwall block
δ→ dip angle: Fault dip is the angle between the fault and a horizontal plane, 0° to 90°
λ → Rake is the direction a hanging wall block moves during rupture, as measured on the plane of the fault. It is measured relative to fault strike, ±180°. For an observer standing on a fault and looking in the strike direction, a rake of 0° means the hanging wall, or the right side of a vertical fault, moved away from the observer in the strike direction (left lateral motion). A rake of ±180° means the hanging wall moved toward the observer (right lateral motion). For any rake>0, the hanging wall moved up, indicating thrust or reverse motion on the fault; for any rake<0° the hanging wall moved down, indicating normal motion on the fault.

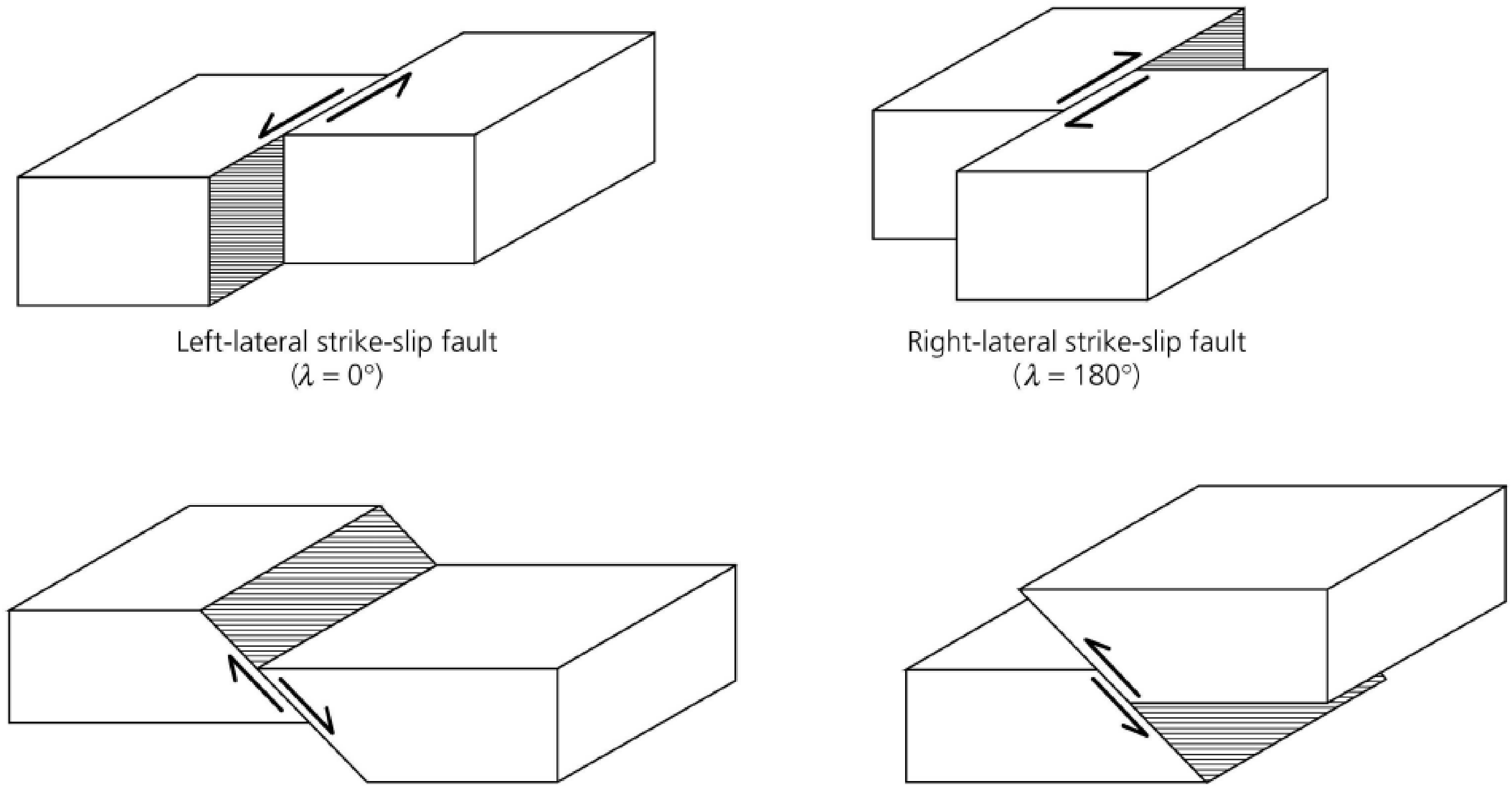
For rake there usually are used two conventions:

1) $-180° < \lambda \le 180°$ by Aki & Richards, 1980
2) $0 \le \lambda < 360°$ by Panza et al, 1973

Reverse fault: 1) $0° < \lambda < 180°$
2) $0° < \lambda < 180°$

Normal fault: 1) $-180° < \lambda < 0°$
2) $180° < \lambda < 360°$

Strike-slip fault: 1) $\lambda = 0°$ left - lateral
2) $\lambda = 180°$ right - lateral



Left-lateral strike-slip fault ($\lambda = 0°$)

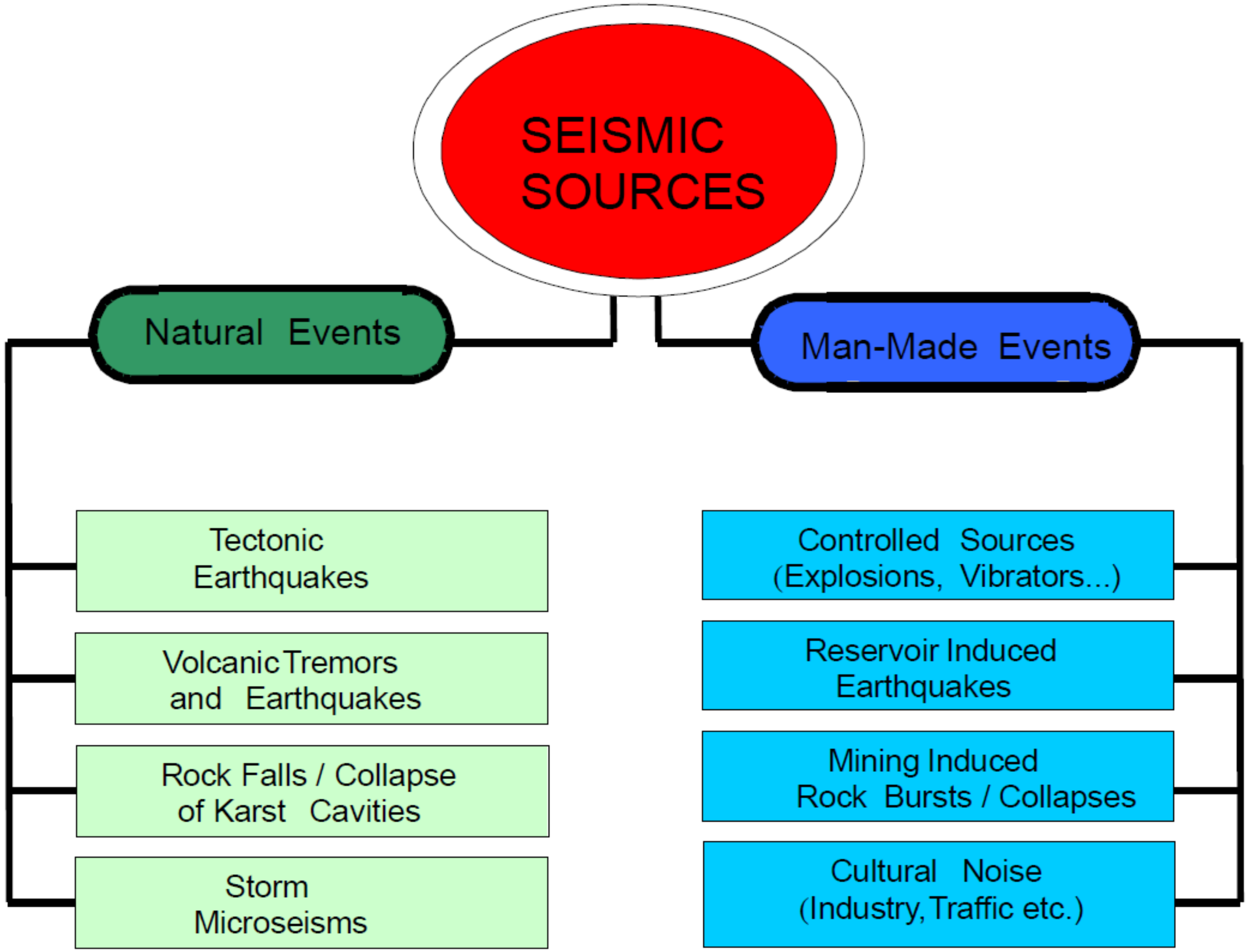
Right-lateral strike-slip fault ($\lambda = 180°$)

Normal dip-slip fault ($\lambda = -90°$)

Reverse dip-slip fault ($\lambda = 90°$)


FAGLIA
posizione originale:
SENZA DEFORMAZIONE
accumulo di energia:
PROGRESSIVA
DEFORMAZIONE
rottura con rilascio di
energia: TERREMOTO
E SPOSTAMENTO
PERMANENTE
4

The fault

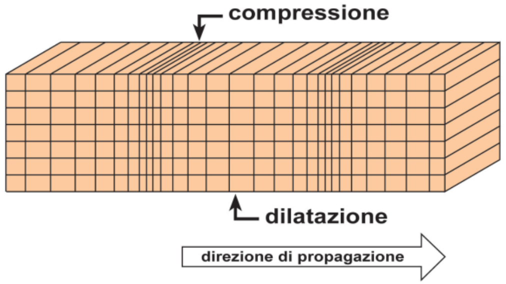


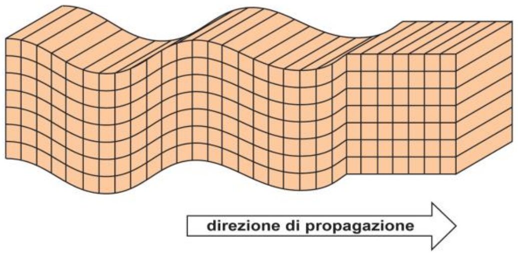
Schematic classification of various types of events that generate seismic waves.

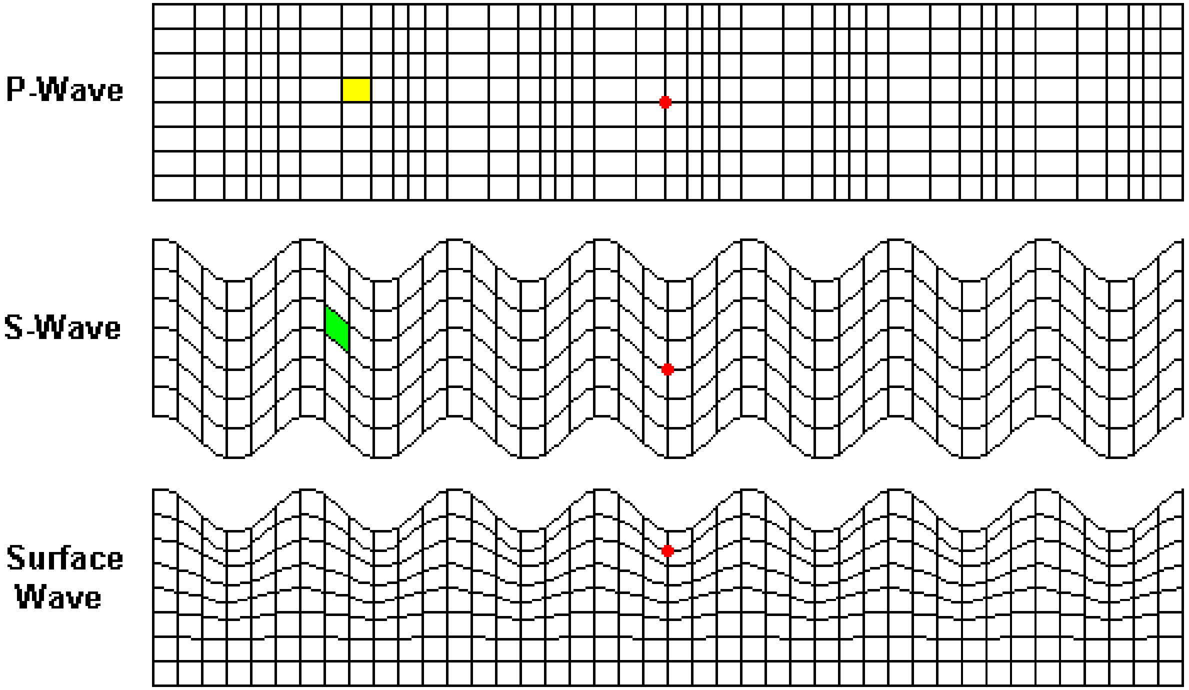
Da: New Manual of Seismological Observatory Practice – NMSOP
CHAPTER 2: Seismic Sources and Source Parameters (Peter Bormann, Michael Baumbach, Günther Bock, Helmut Grosser, George L. Choy and John Boatwright)

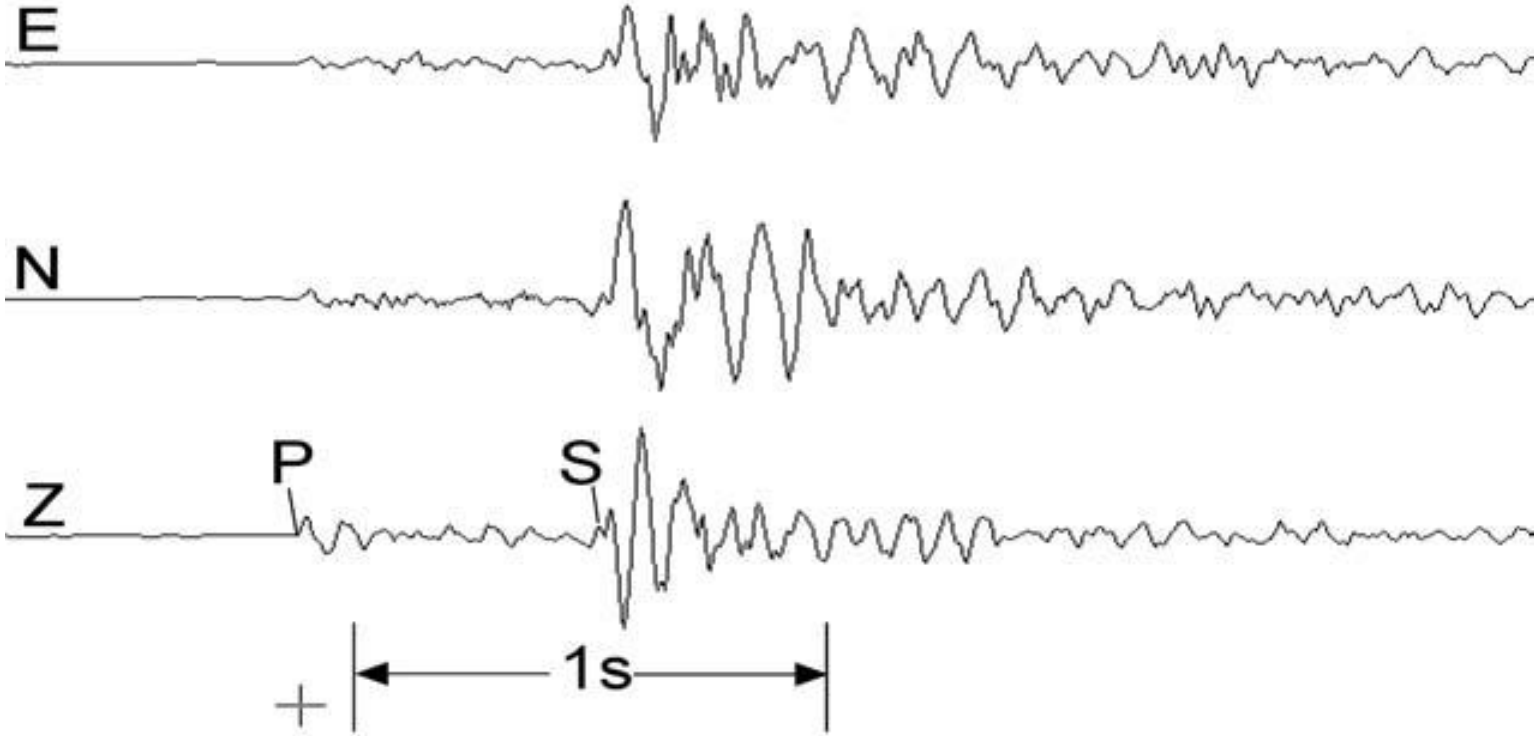
ONDA P

ONDA S


compressione
dilatazione
direzione di propagazione

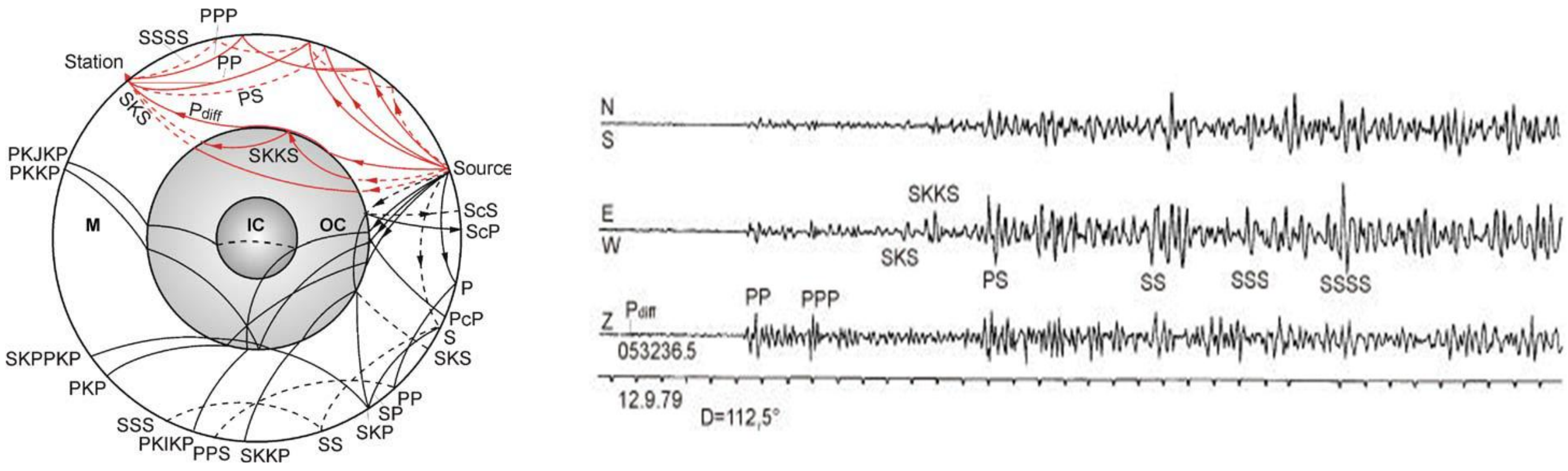

direzione di propagazione


P-Wave
S-Wave
Surface
Wave



Ie three velocity components of the digital proportional ground records of P and S waves from a local event, an aftershock of the Killari-Latur earthquake, India (18.10.1993), at a hypocentral distance of about 5.3 km.

Da: New Manual of Seismological Observatory Practice – NMSOP
CHAPTER 2: Seismic Wave Propagation and Earth Models (P. Bormann, E. R. Engdahl and R. Kind)

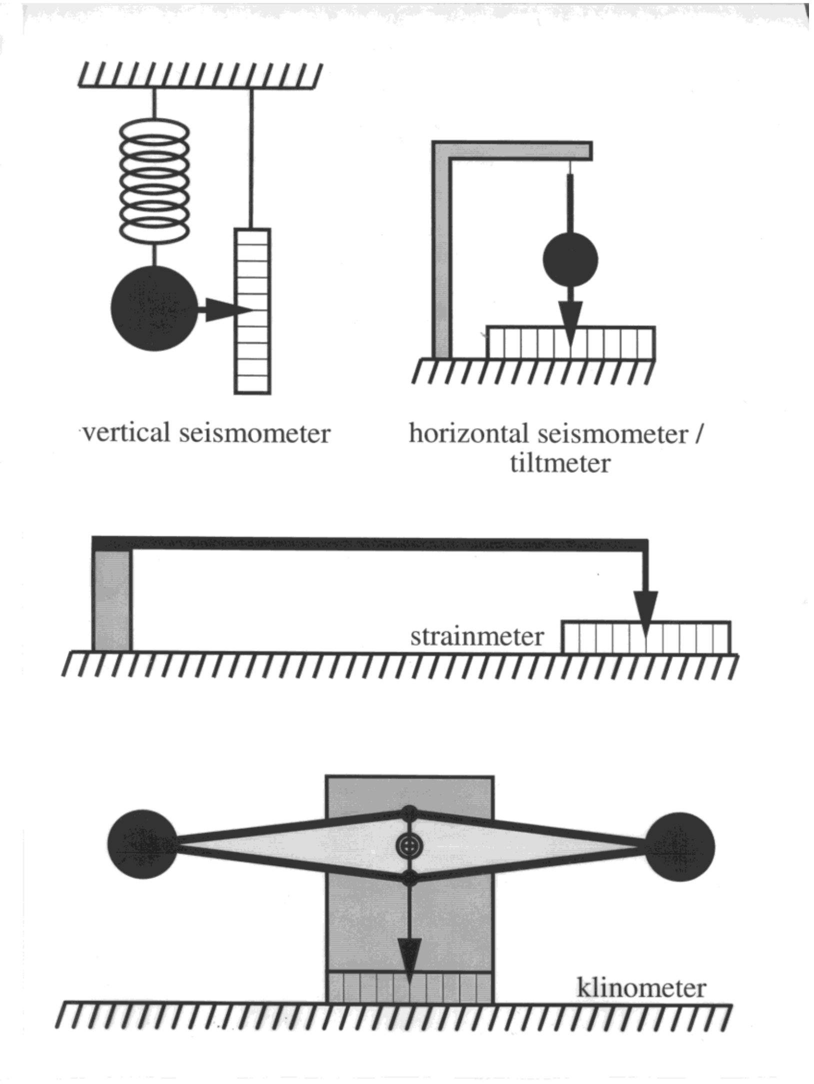


Top: Seismic ray paths through the Earth's mantle (M), outer core (OC) and inner core (IC) with respective phase symbols according to international nomenclature. Solid lines: P rays: dashed lines: S rays. Red rays refer to body waves related to broadband 3-component Kirnos SKD seismograms recorded at the MOX station in Germany for an earthquake at an epicenter distance of 112.5°.

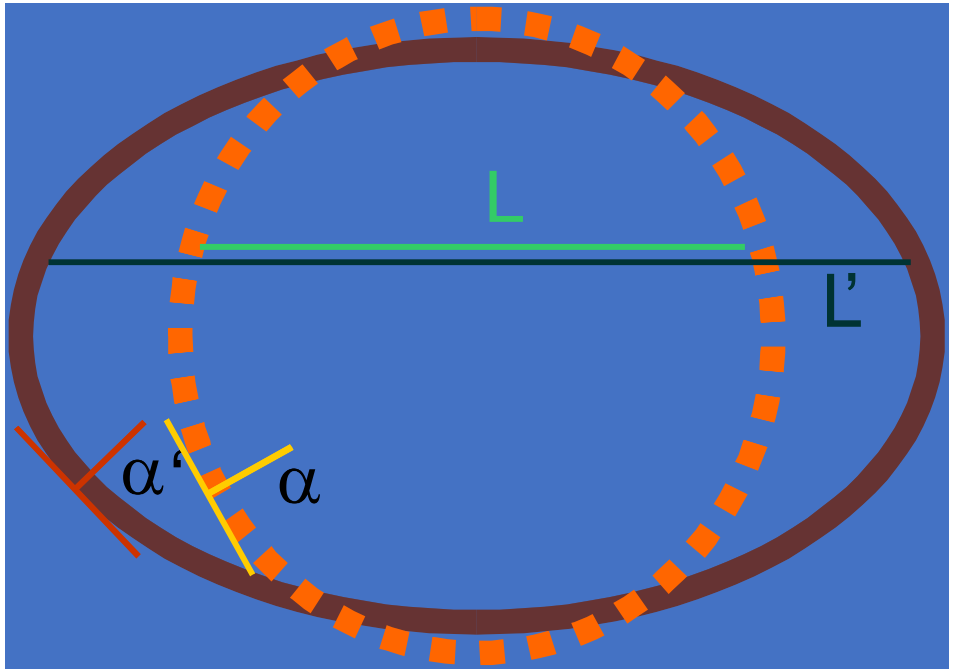
2 types of seismic sensors:

Strainmeters and clinometers.
They measure the relative motion of a point with respect to a second point

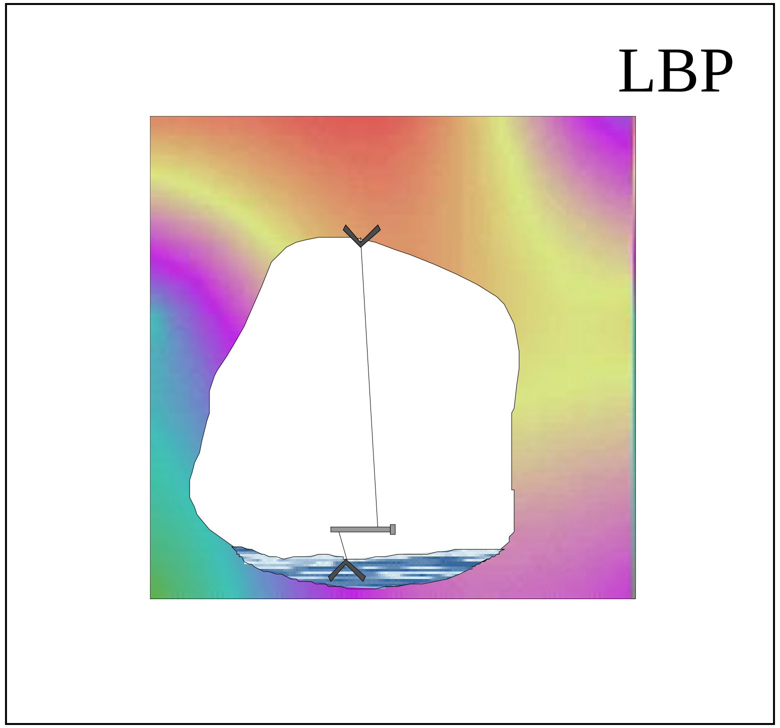
Inertial.
They measure the motion of the ground relative to a suspended mass


vertical seismometer
horizontal seismometer / tiltmeter
strainmeter
klinometer

Estensimetri e clinometri

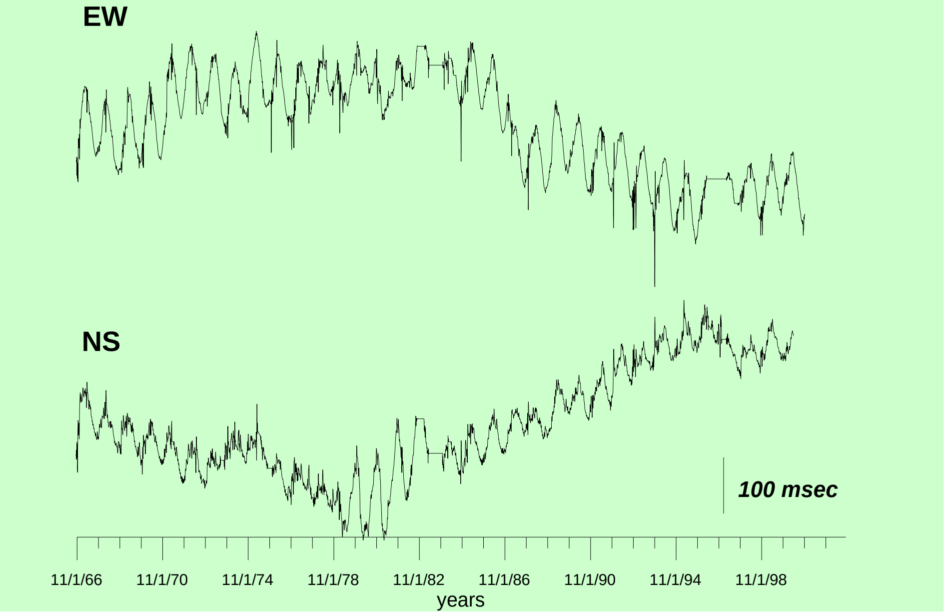


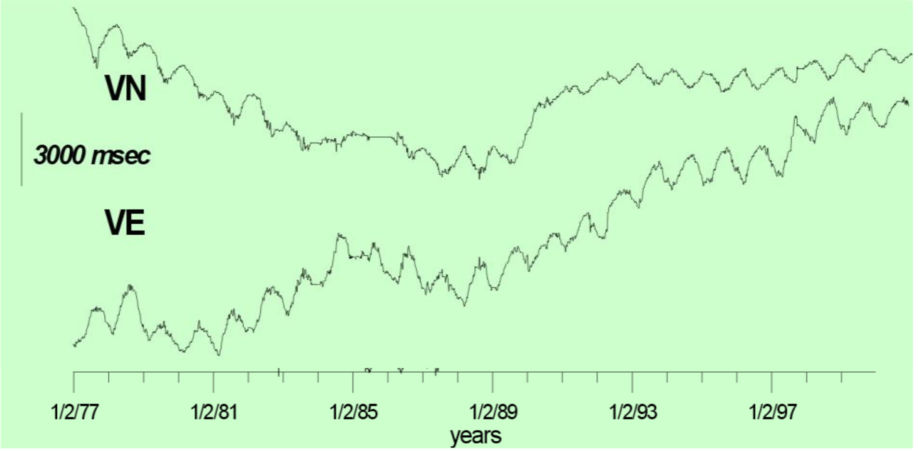
Pendoli di Grotta Gigante

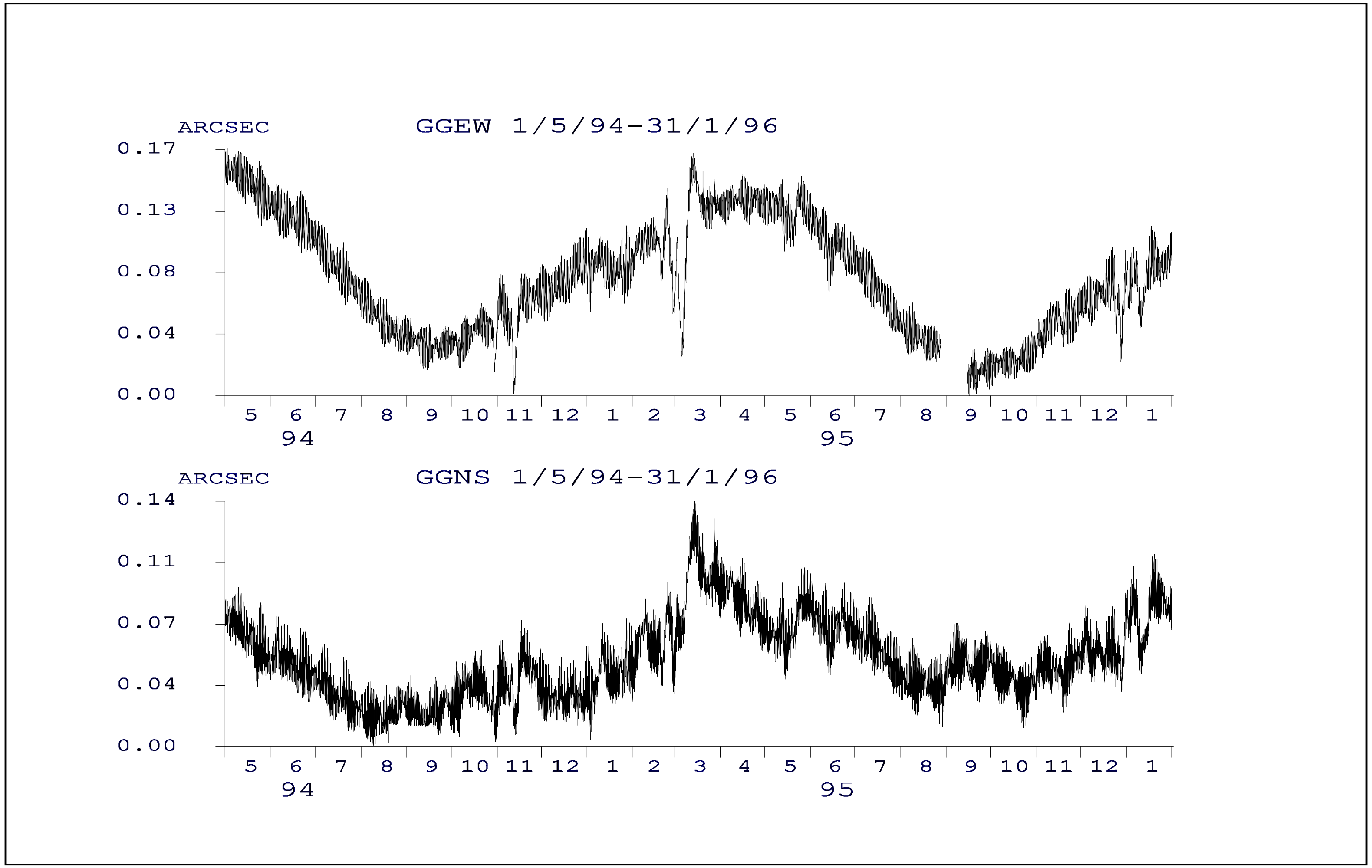


LBP – Grotta Gigante

SBP – Grotta di Villanova



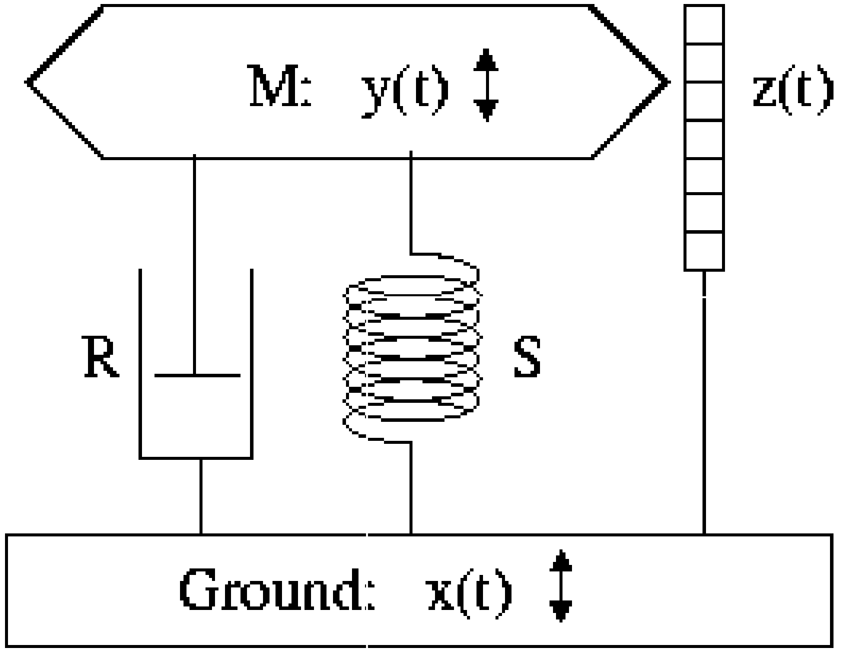




Example of LBP recordings.

Visible are: annual effects (thermoelastic effects of upper crust layers); the tide; some effects due to flooding of the Timavo underground river.

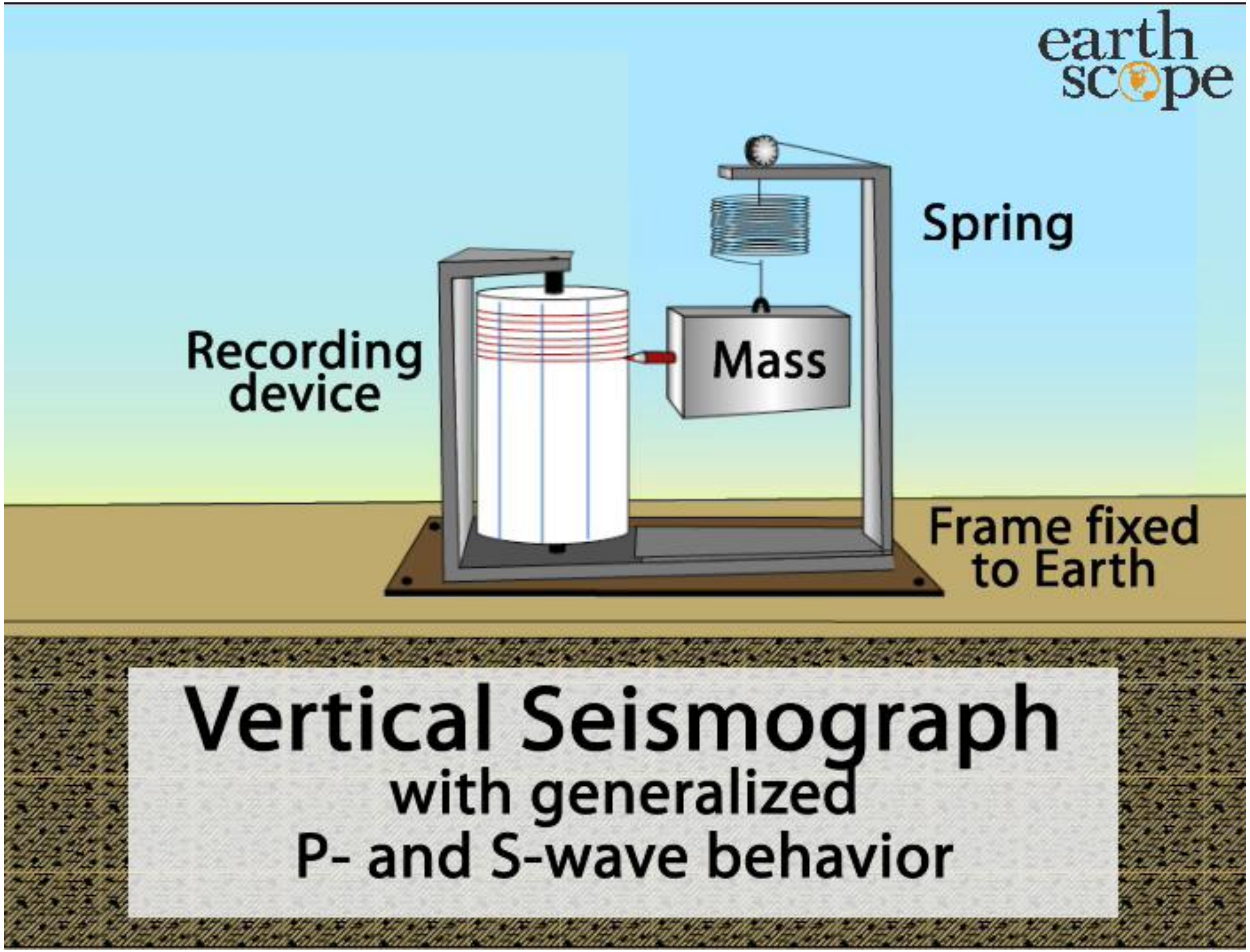
Sismografo

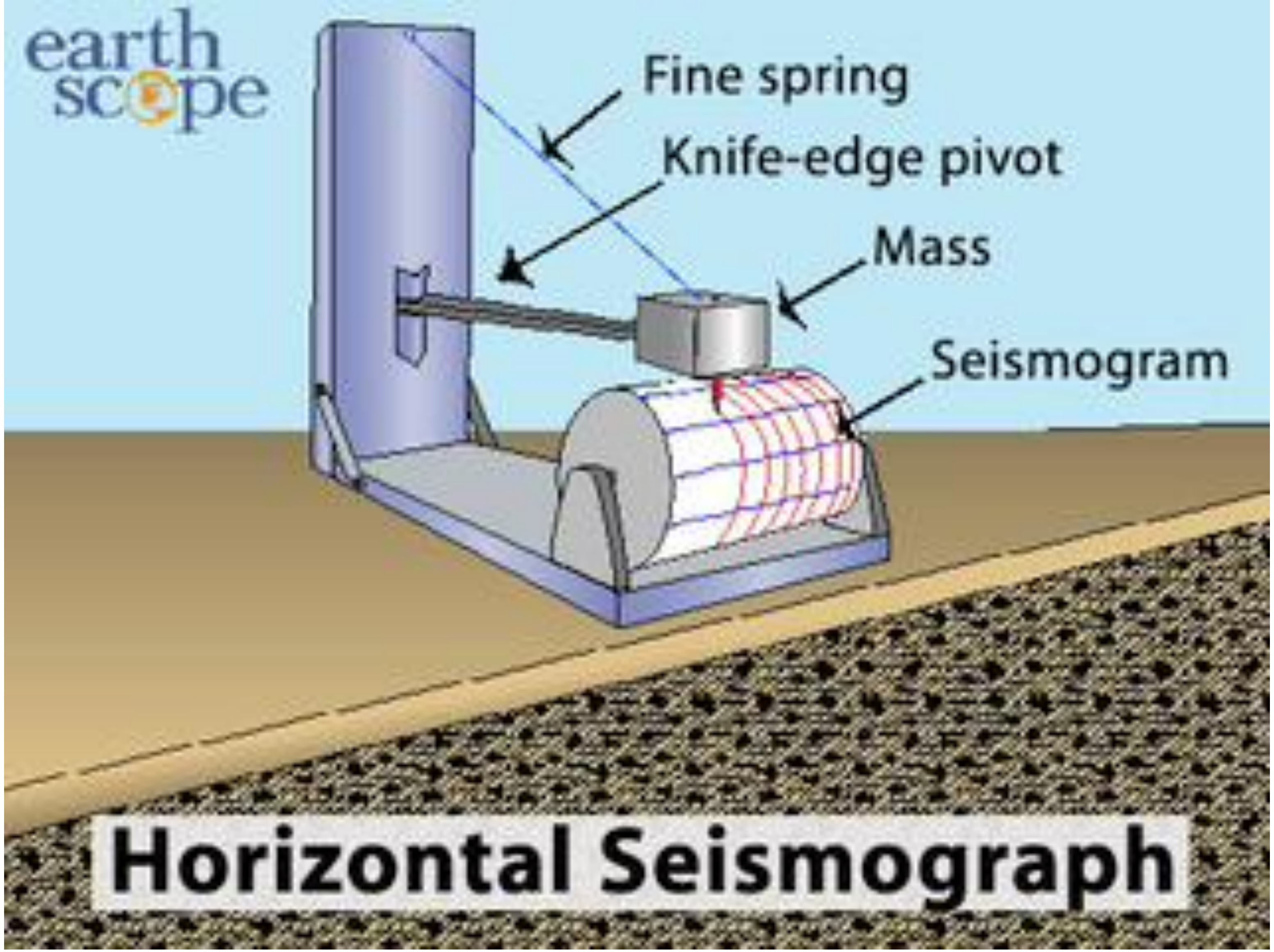


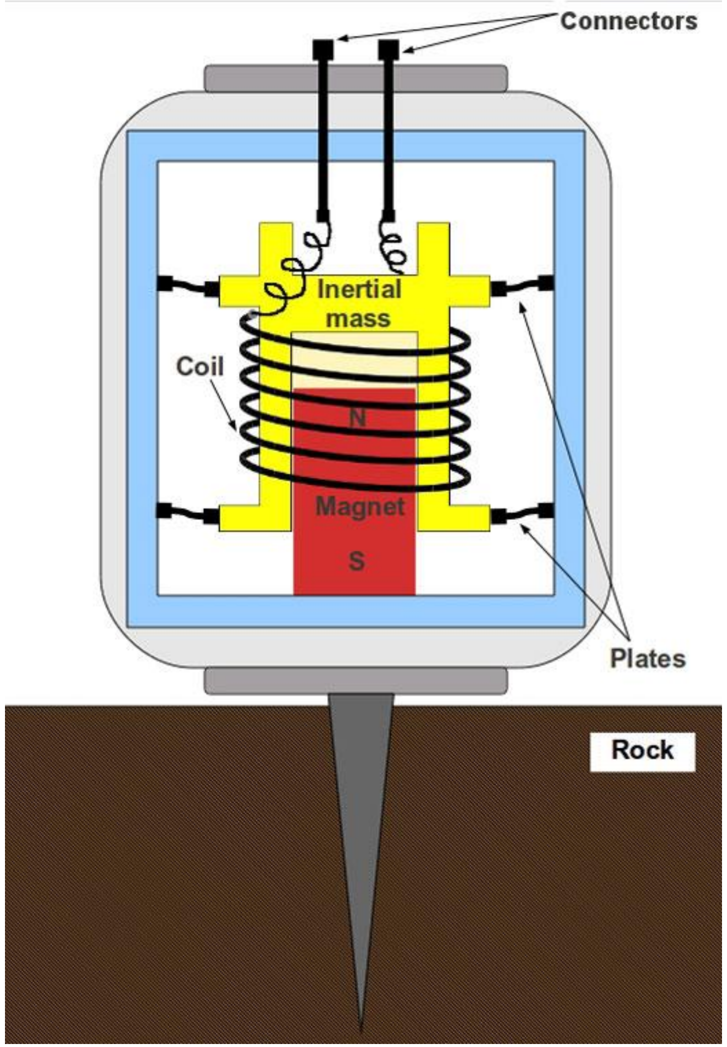
To measure the displacement of the ground on which the instrument rests,

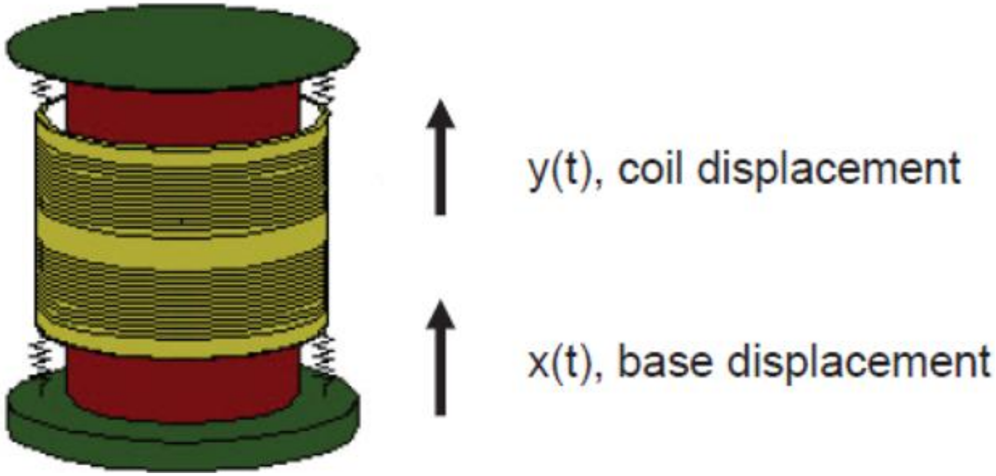
the principle of inertia

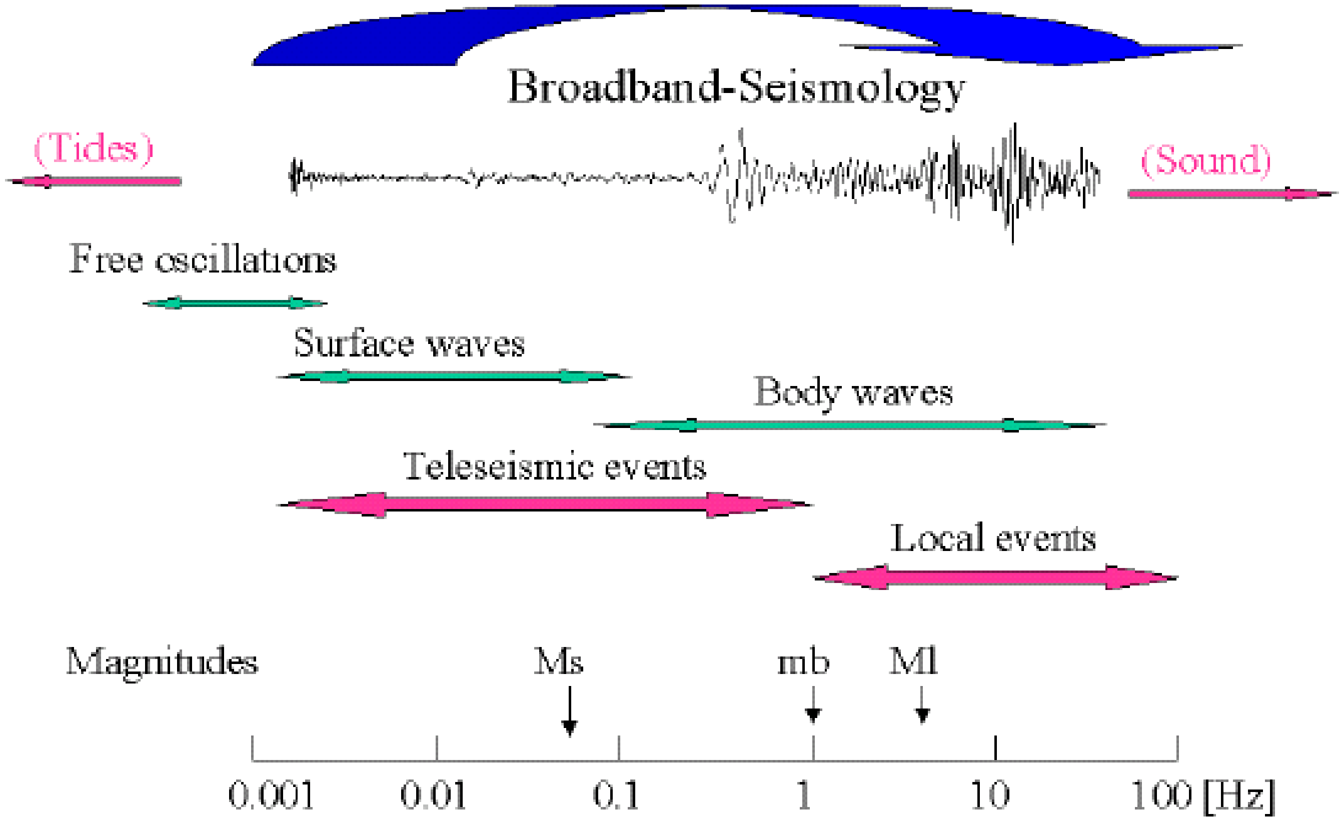
for sufficiently rapid ground motion a suspended mass will remain stationary and give us a reference point on which to measure ground motion


earth scope
Spring
Recording device
Mass
Frame fixed to Earth
Vertical Seismograph
with generalized
P- and S-wave behavior


earth scope
Fine spring
Knife-edge pivot
Mass
Seismogram
Horizontal Seismograph


Connectors
Inertial mass
Coil
N
Magnet
S
Plates
Rock

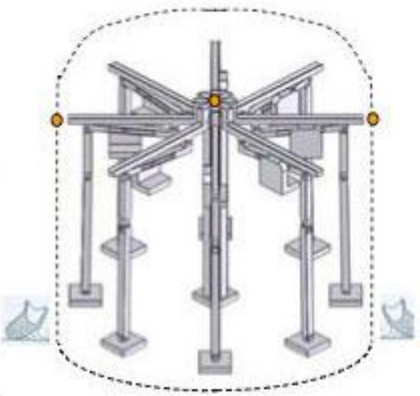

y(t), coil displacement
x(t), base displacement

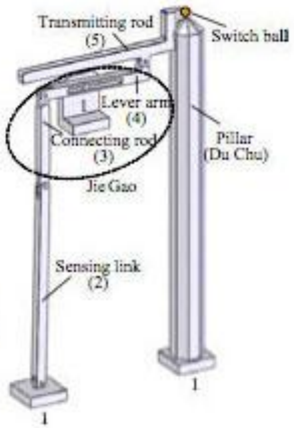

Broadband-Seismology
(Tides)
(Sound)
Free oscillations
Surface waves
Body waves
Teleseismic events
Local events
Magnitudes
Ms
mb
Ml
0.001
0.01
0.1
1
10
100 [Hz]

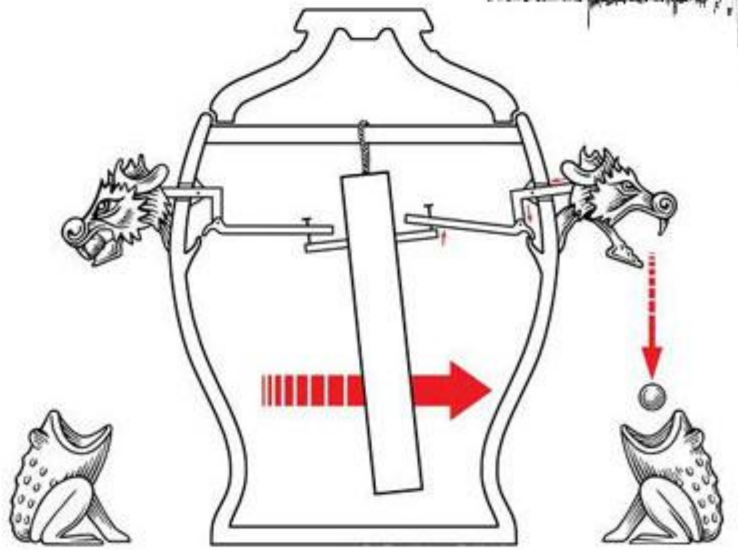
Registrazioni sismologiche di alta qualità

1) **Alta “percezione”** (capacità dell’installazione di registrare quanti più eventi possibile).
2) **Completezza del data set** (registrazioni continue e stabili nello spazio e nel tempo)
3) **Alta fedeltà** delle registrazioni al movimento del terreno.
4) **Rappresentatività** dei dati rispetto alle finalità della rete.

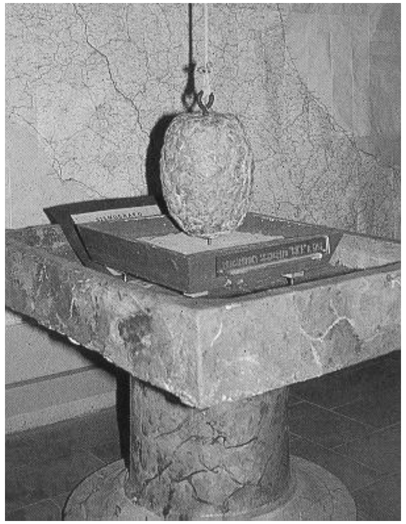
Chang Heng 132 a.c





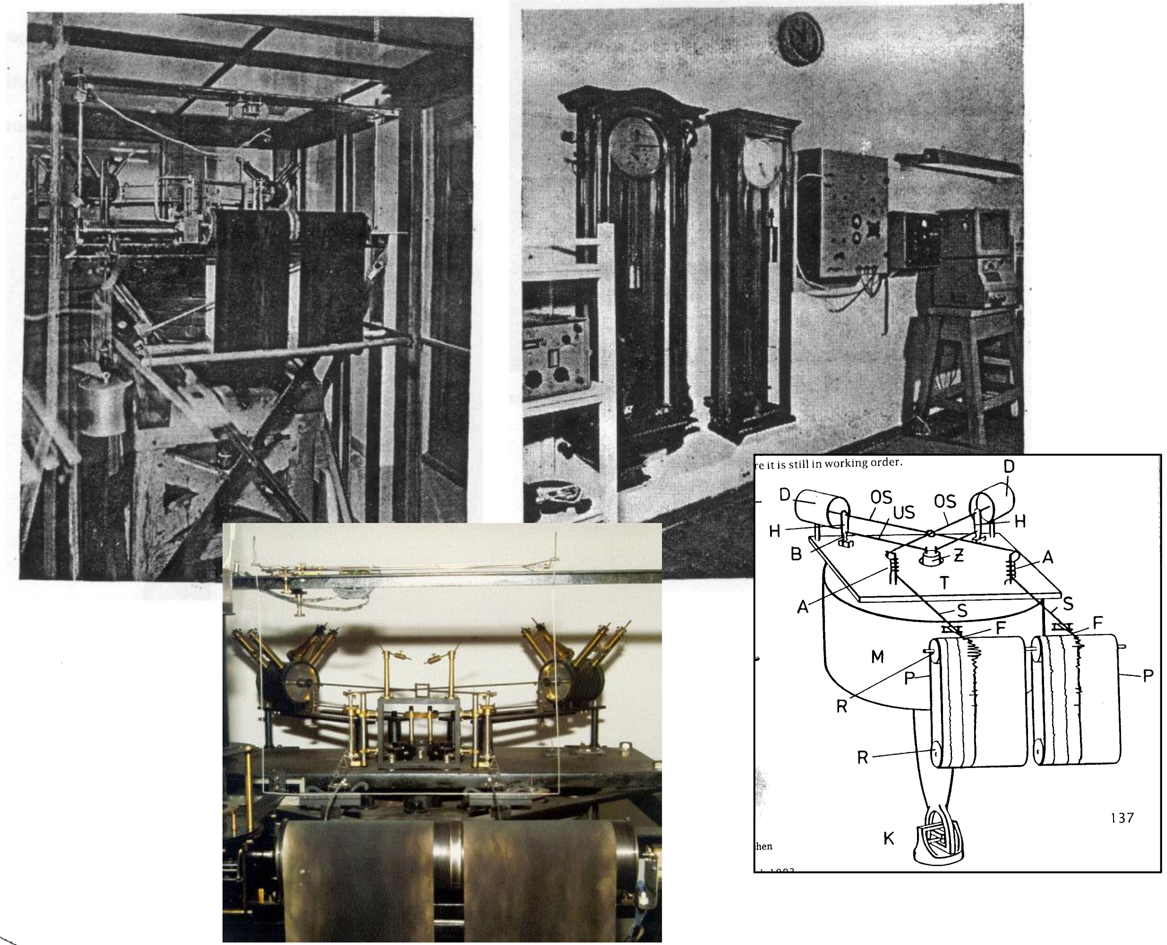


Bina 1751

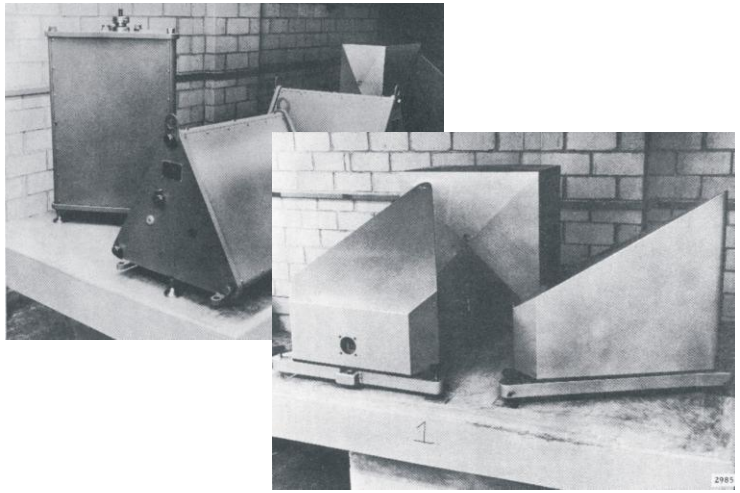


Cacciatore 1818

Wiechert 1903



TRI-117 WWSSN



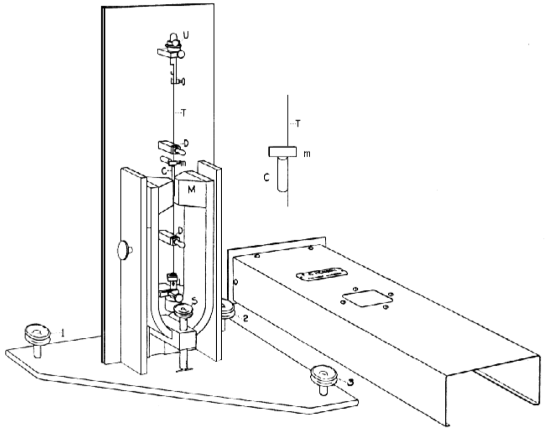


Fig. 2

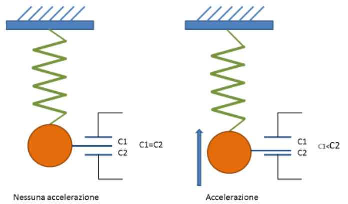
Wood-Anderson 1922

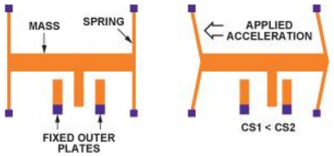

STS 1
TRI

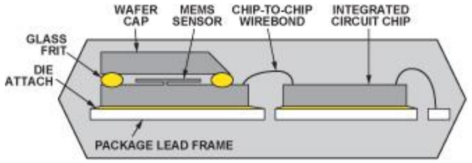

VINO

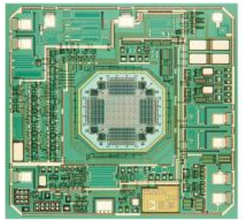

STS 2

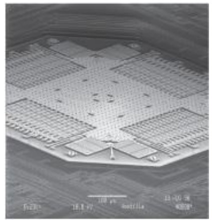
Accelerometri MEMS

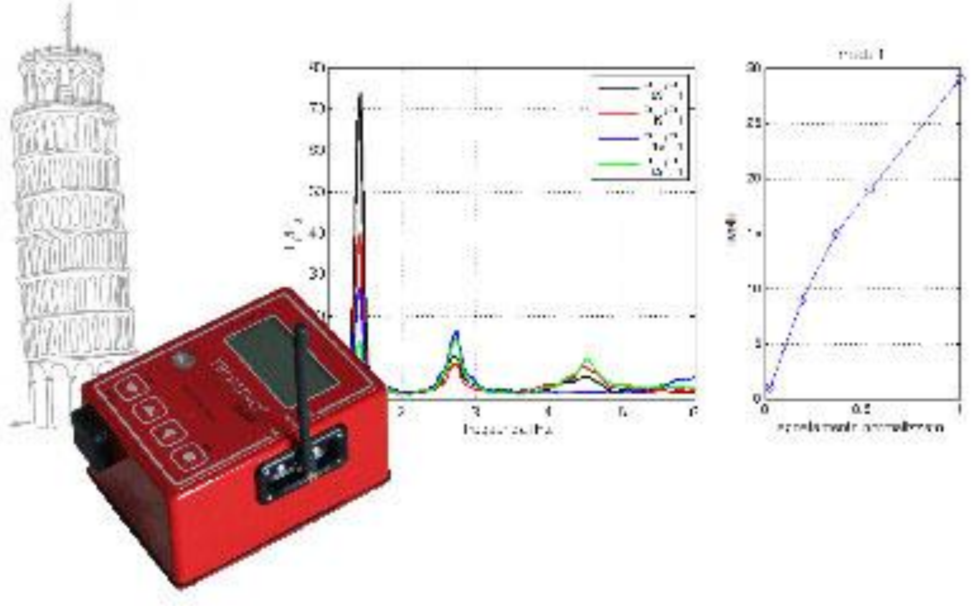




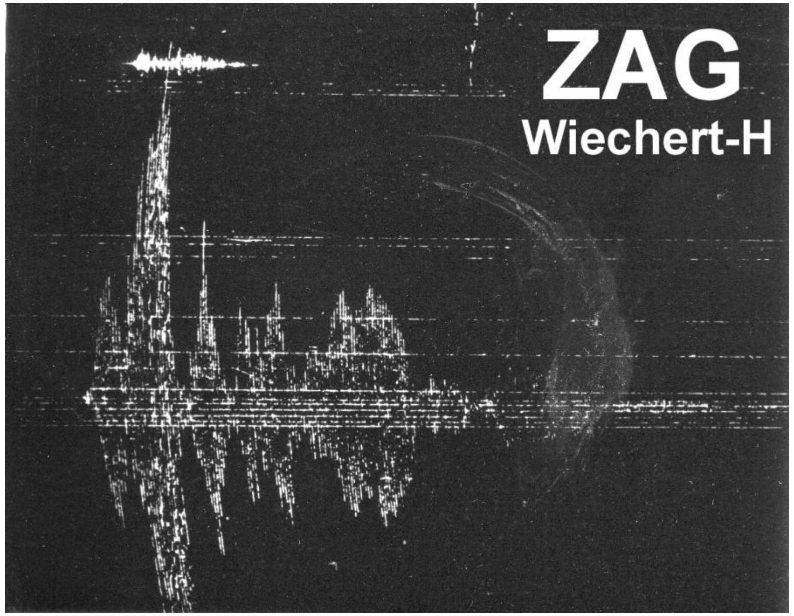


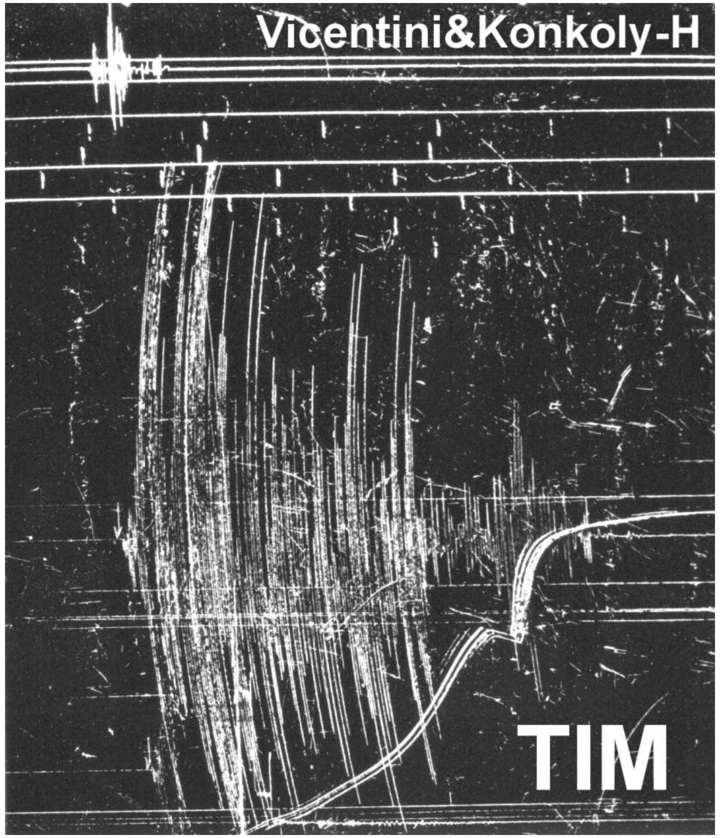


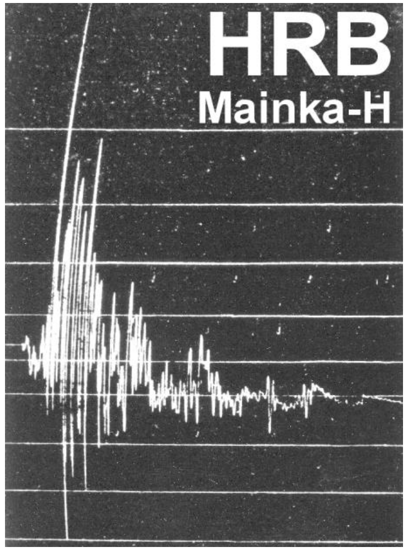




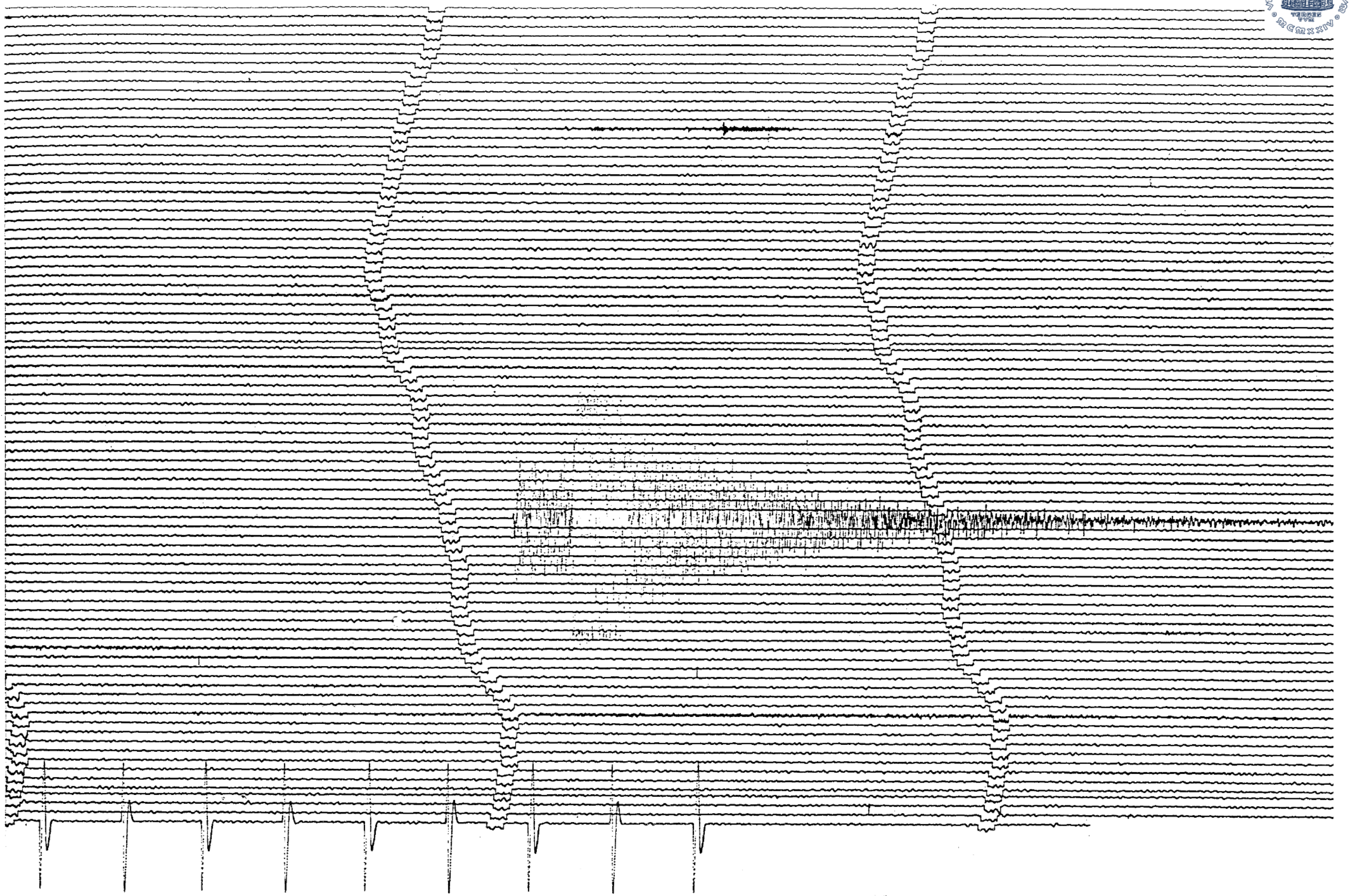
Rete Accelerometrica del FVG-Veneto



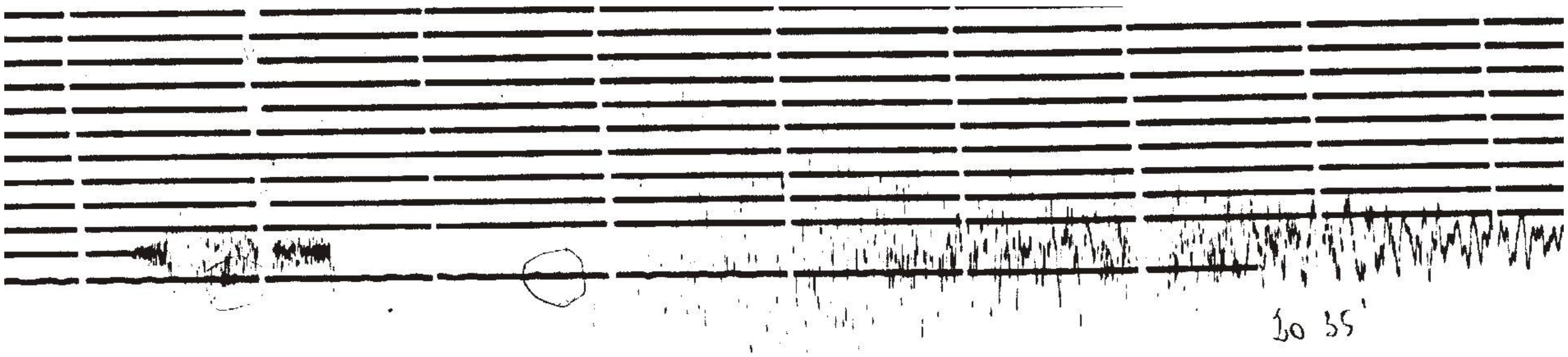




Kecskemét 1911, M 5.6



Friuli 1976 Ml 6.5 – Wood-Anderson

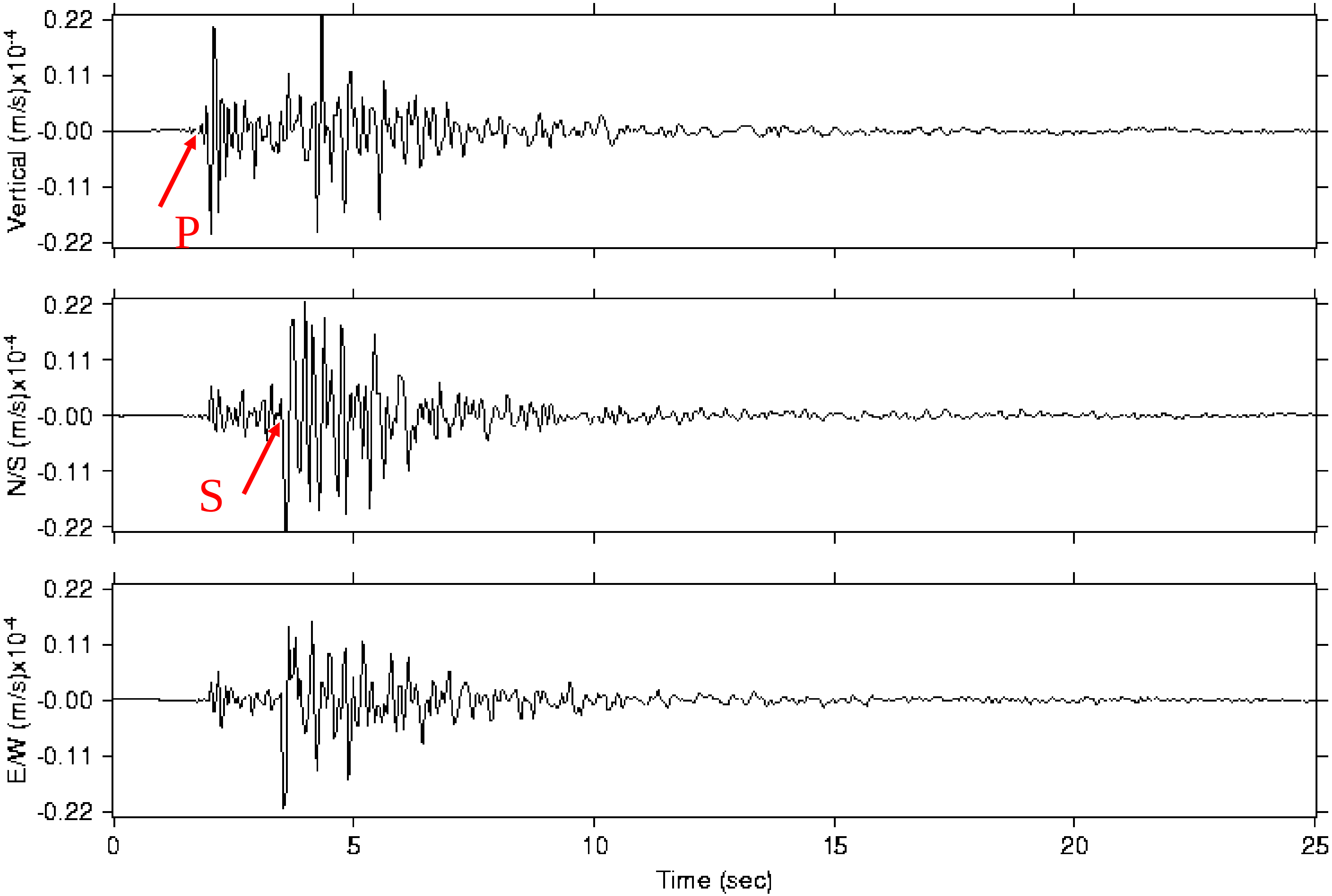



Regione Autonoma

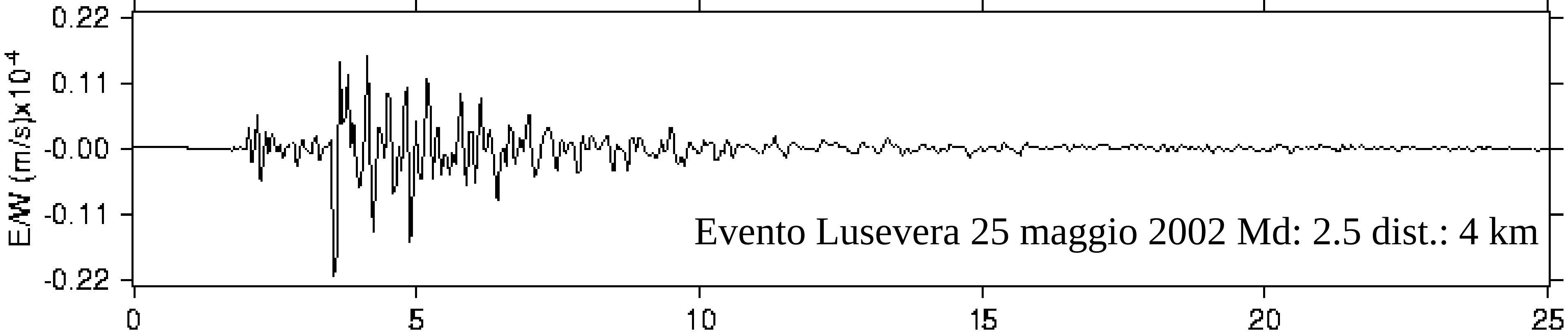

31/7/2000 19:01

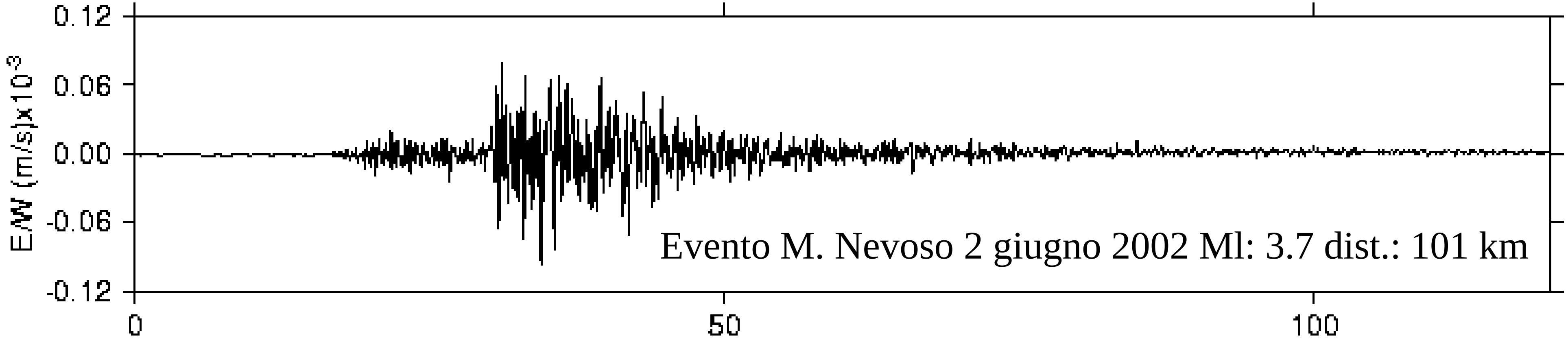
VINO

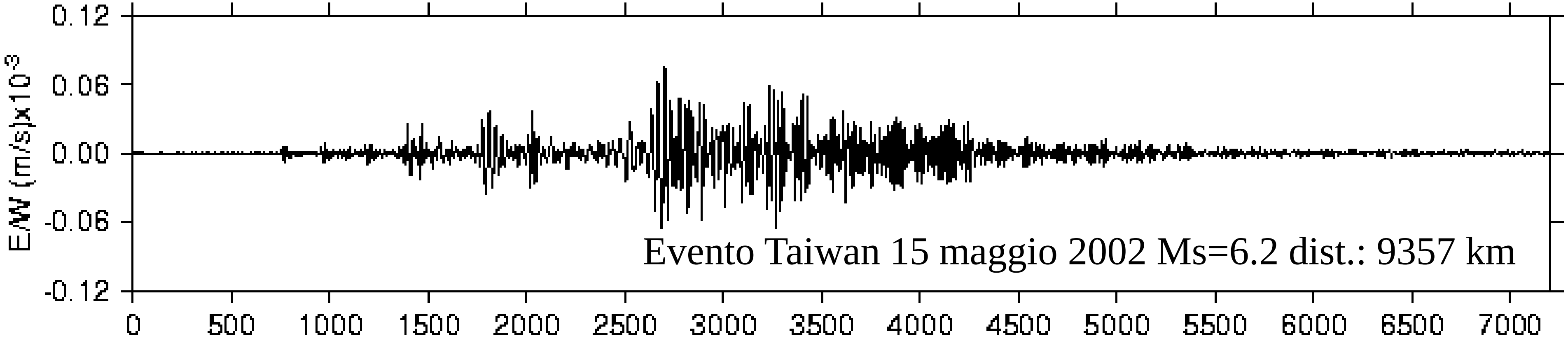
Evento Lusevera 25 maggio 2002 Md: 2.5 dist.: 4 km

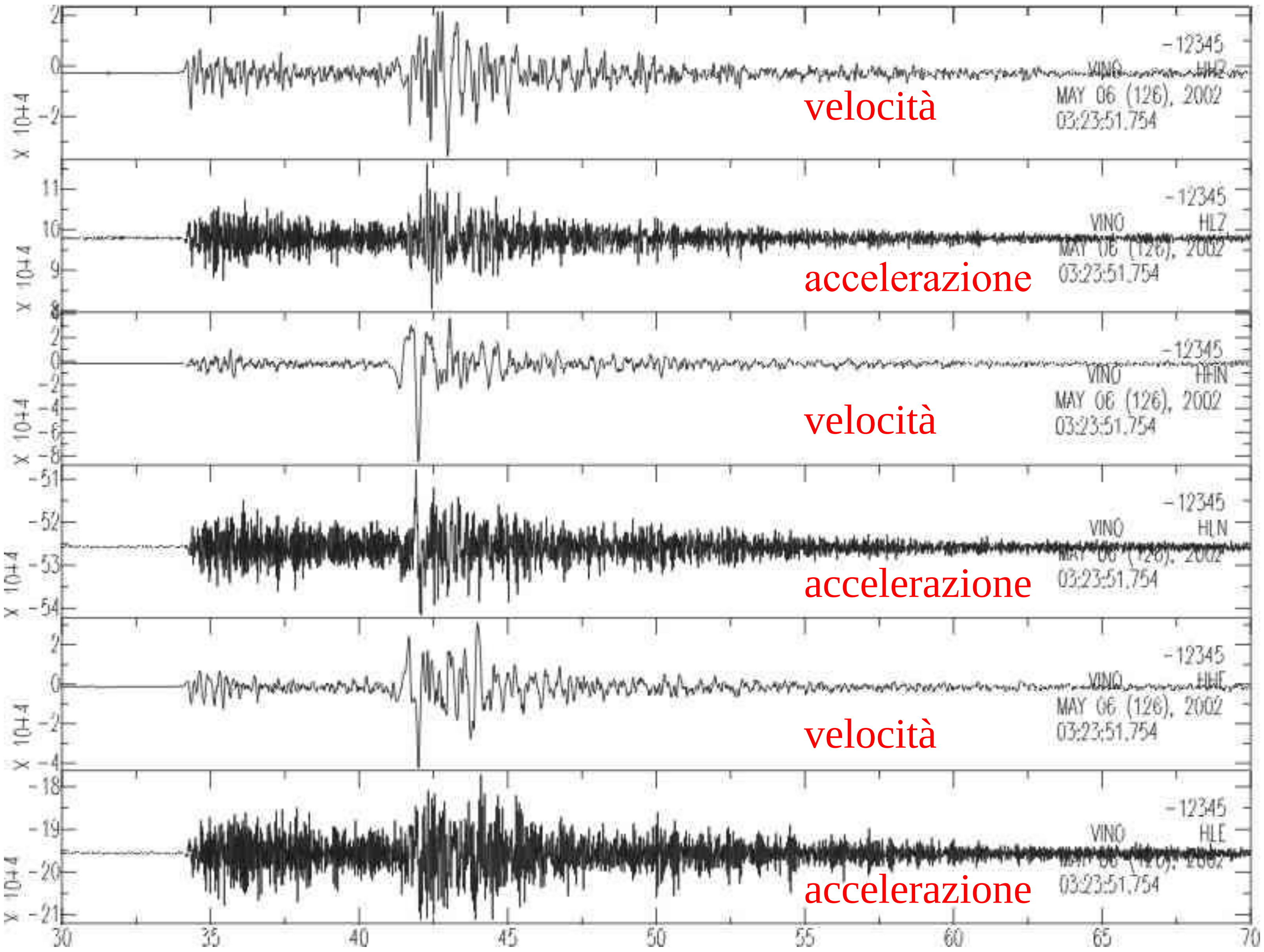


VINO

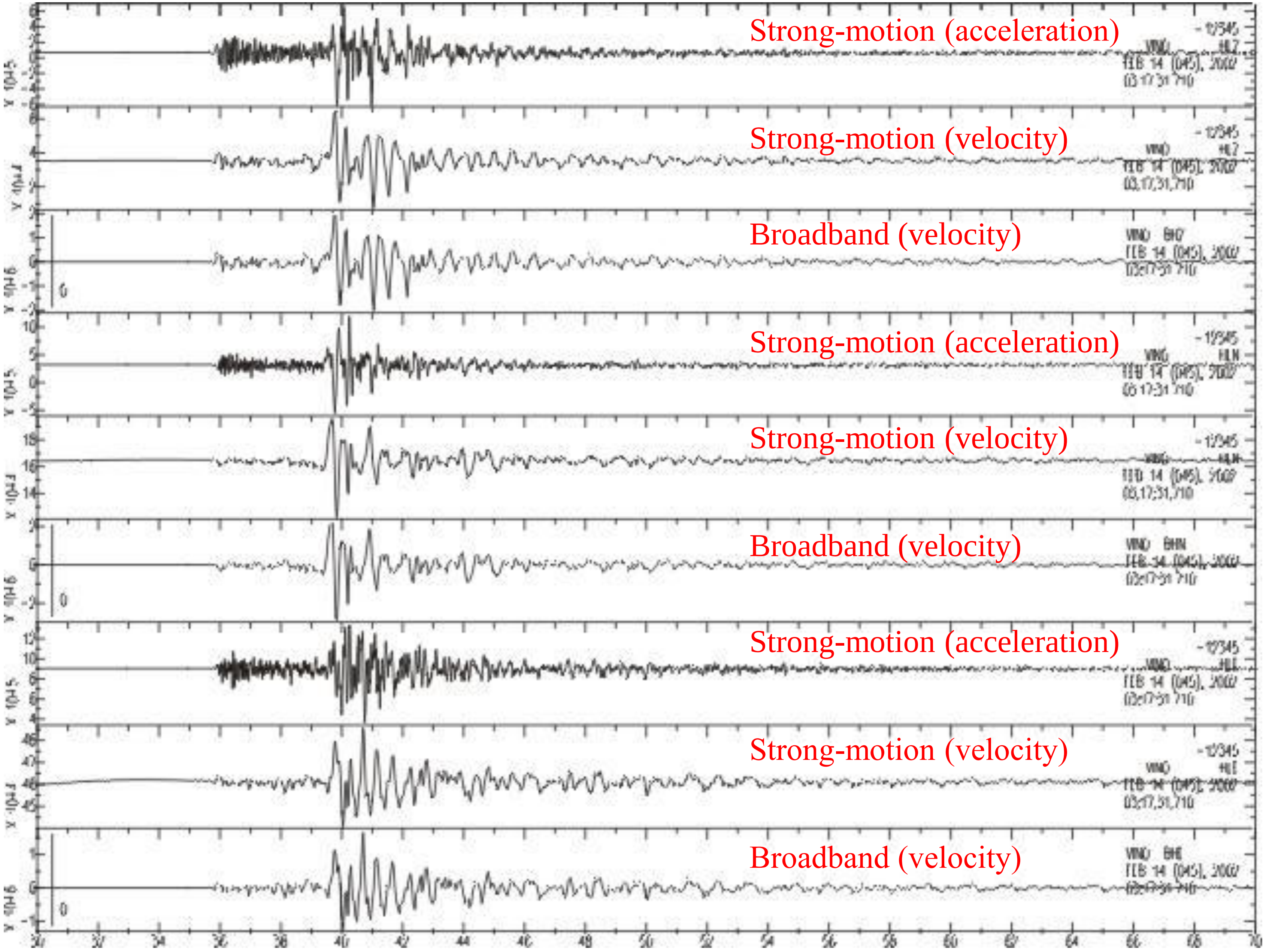

E/W (m/s)x10^{-4}
0.22
0.11
-0.00
-0.11
-0.22
0
5
10
15
20
25
Evento Lusevera 25 maggio 2002 Md: 2.5 dist.: 4 km


E/W (m/s)x10^{-3}
0.12
0.06
0.00
-0.06
-0.12
0
50
100
Evento M. Nevoso 2 giugno 2002 Ml: 3.7 dist.: 101 km

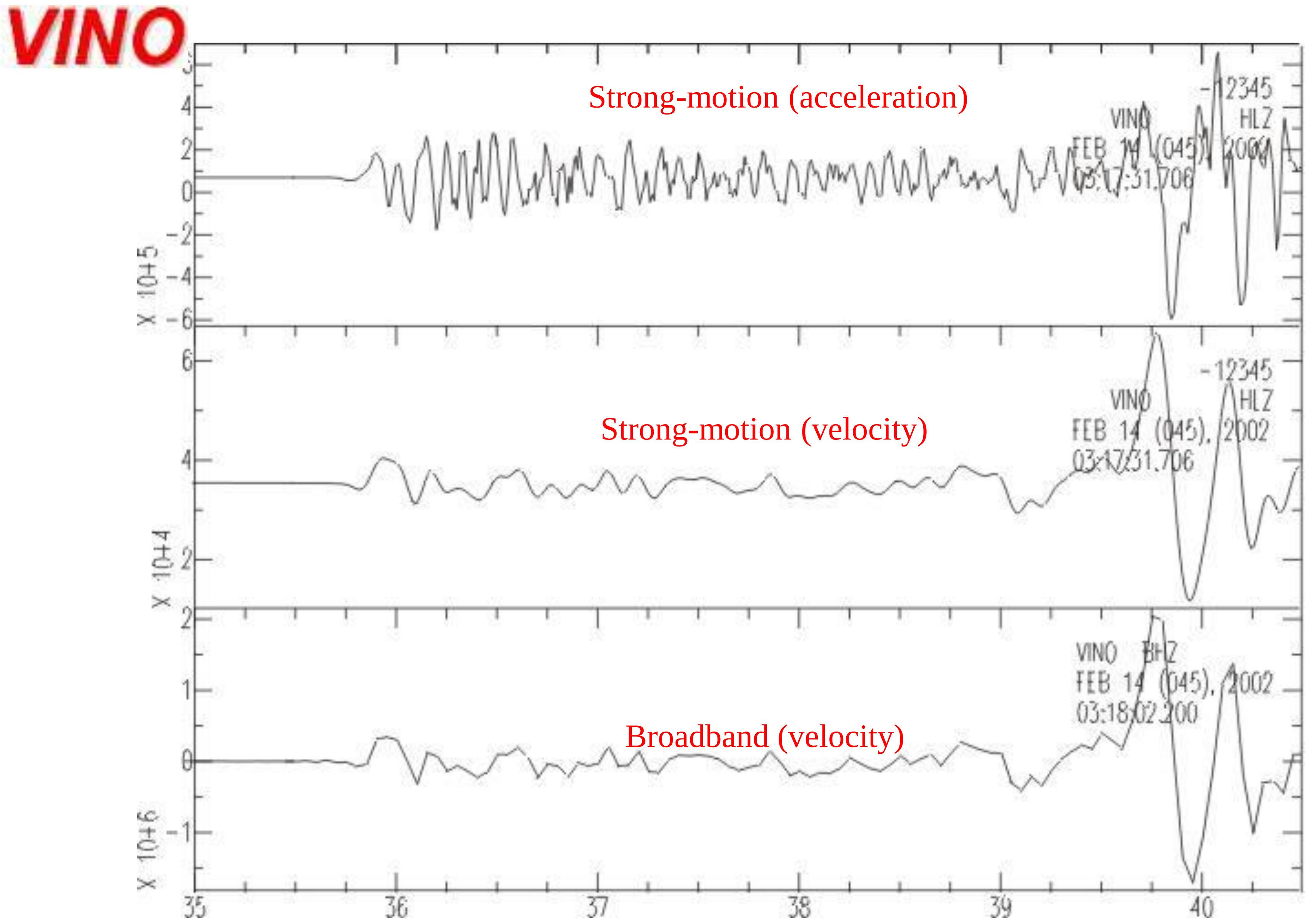

E/W (m/s)x10^{-3}
0.12
0.06
0.00
-0.06
-0.12
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
Evento Taiwan 15 maggio 2002 Ms=6.2 dist.: 9357 km

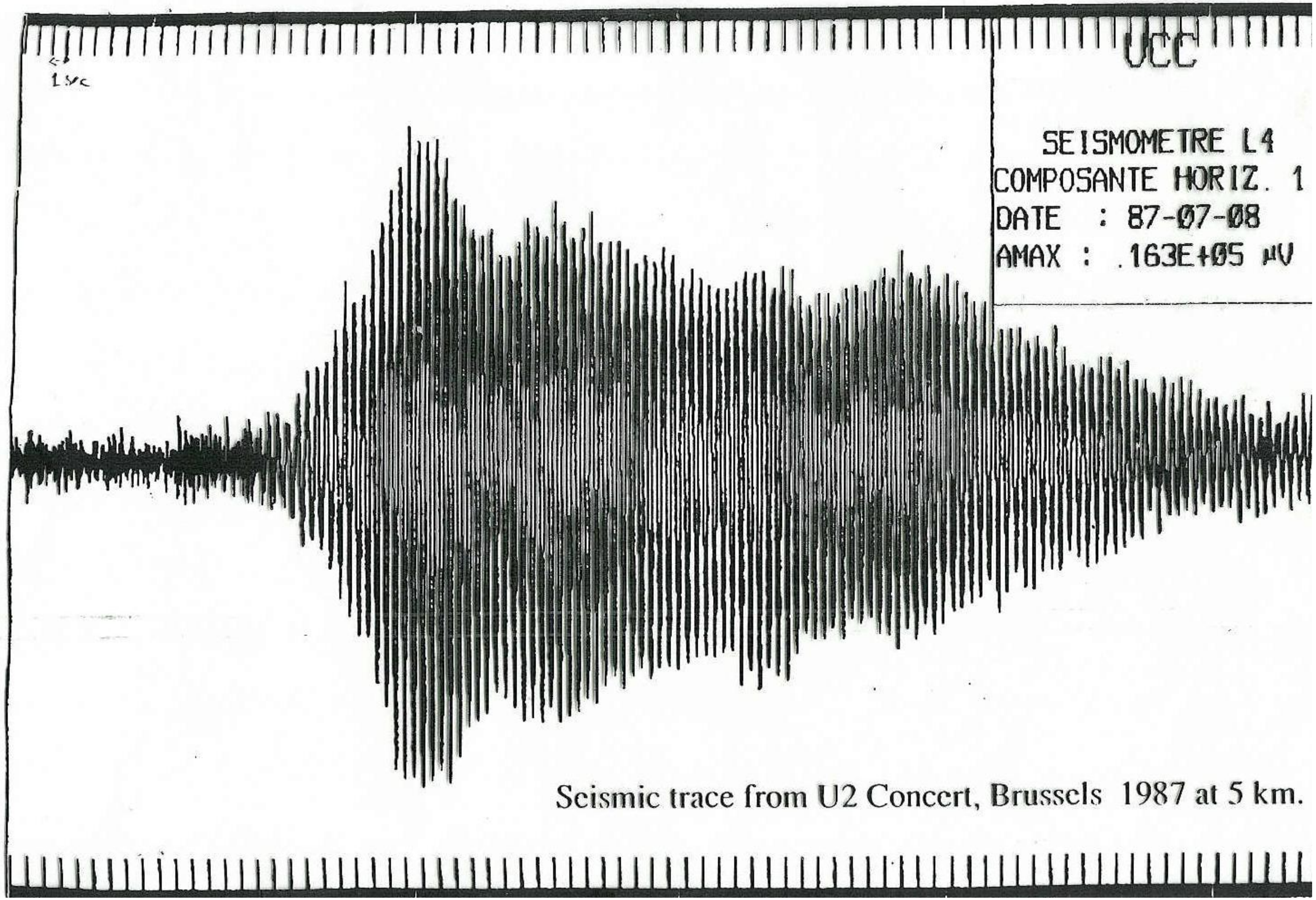

velocità
accelerazione
velocità
accelerazione
velocità
accelerazione
-12345
VINO
HHZ
HLZ
HHN
HLN
HHE
HLE
MAY 06 (126), 2002
03:23:51.754
X 10+4
30
35
40
45
50
55
60
65
70

Evento Carnia 6 maggio 2002 3:17:31.710

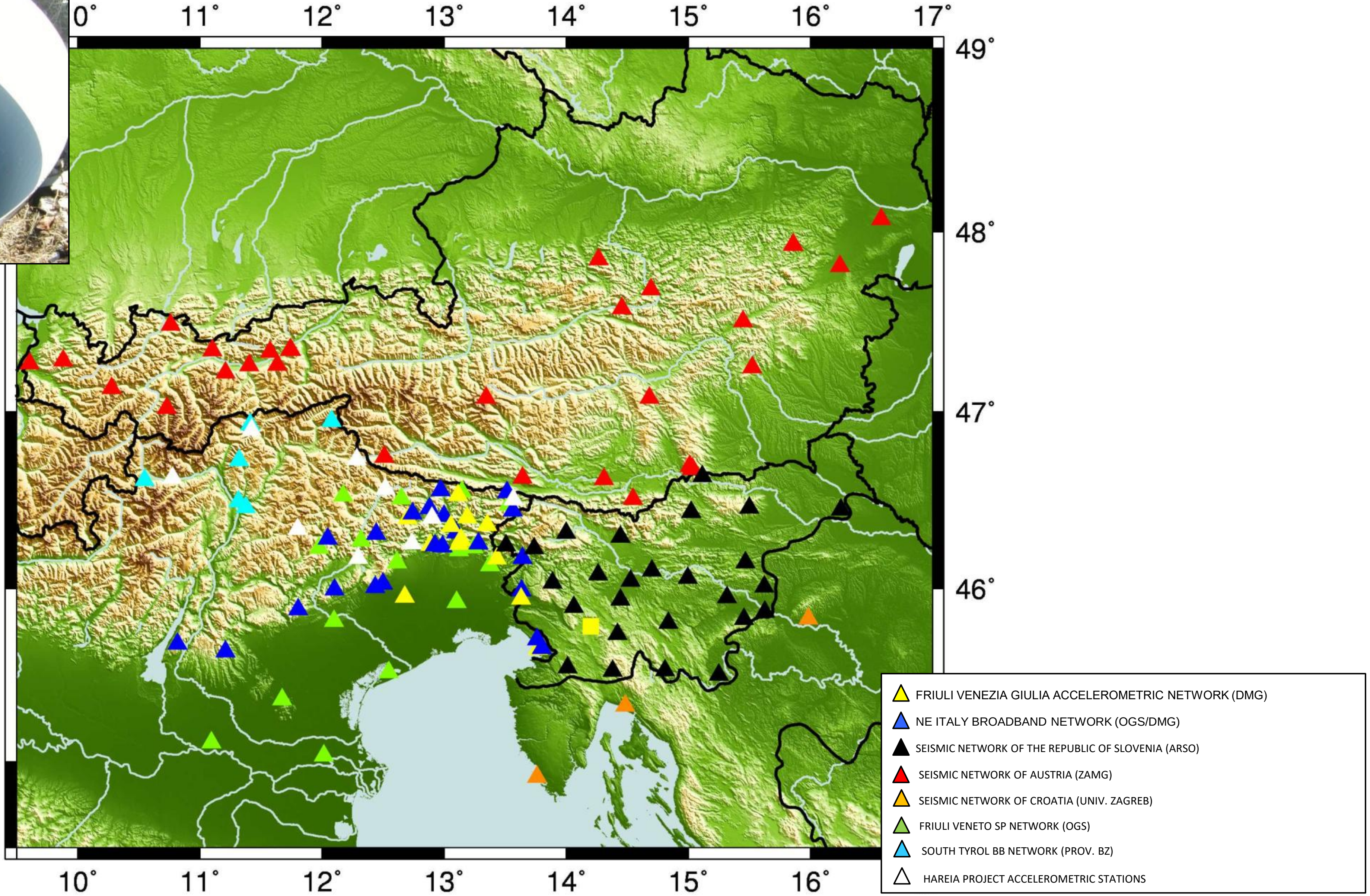


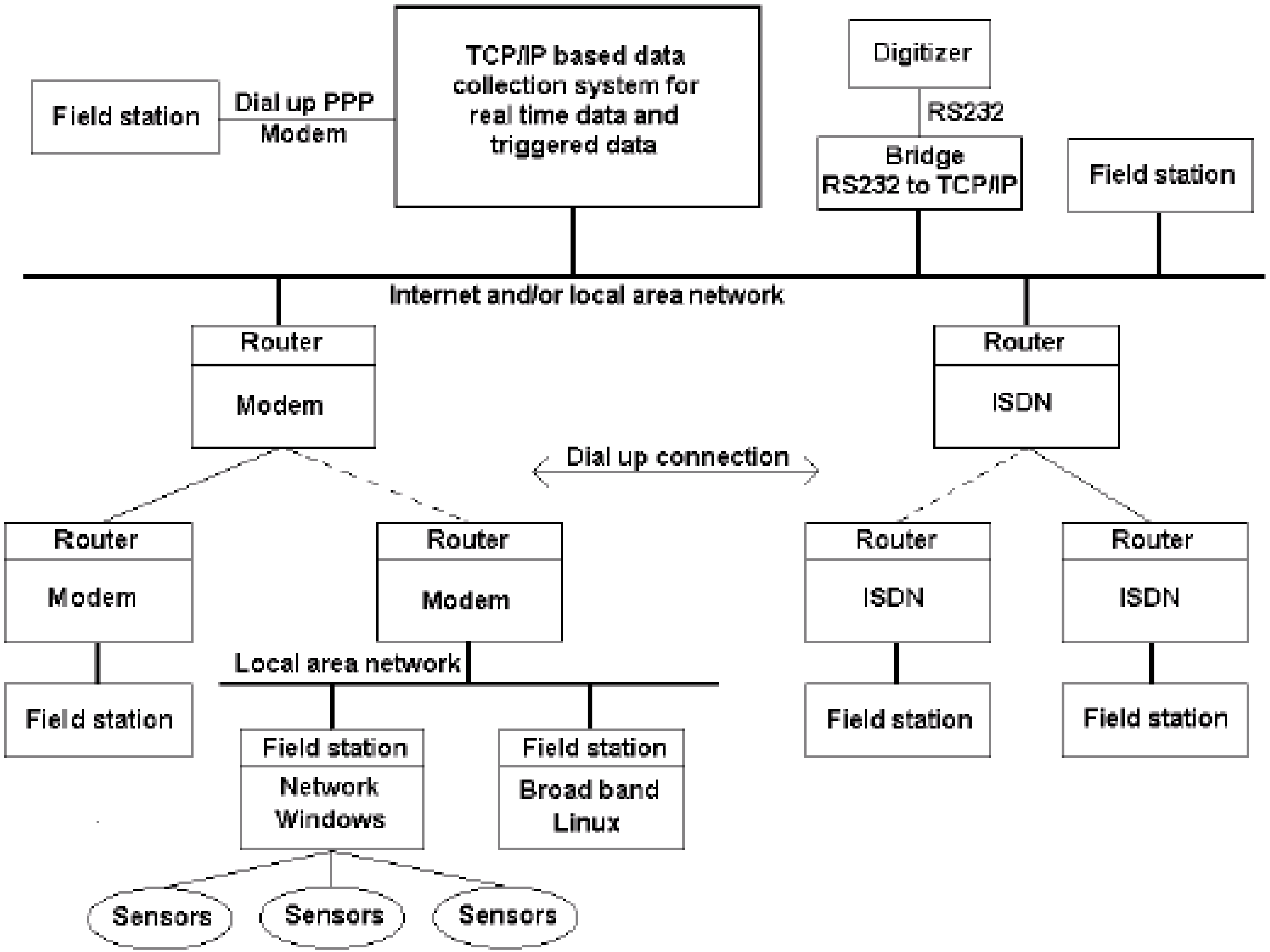
Evento Carnia 6 maggio 2002 3:17:31.710



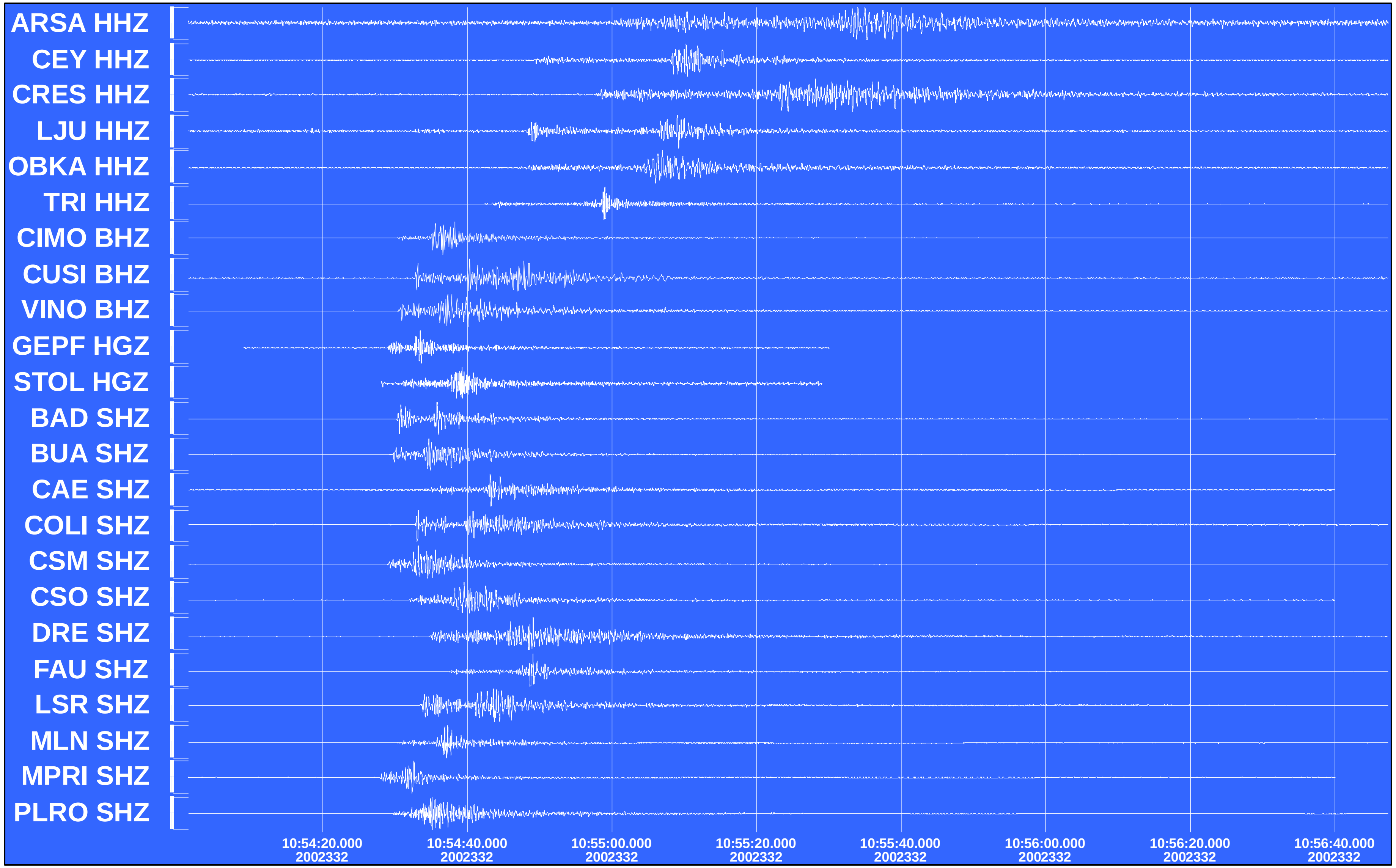


Seismic trace from U2 Concert, Brussels 1987 at 5 km.

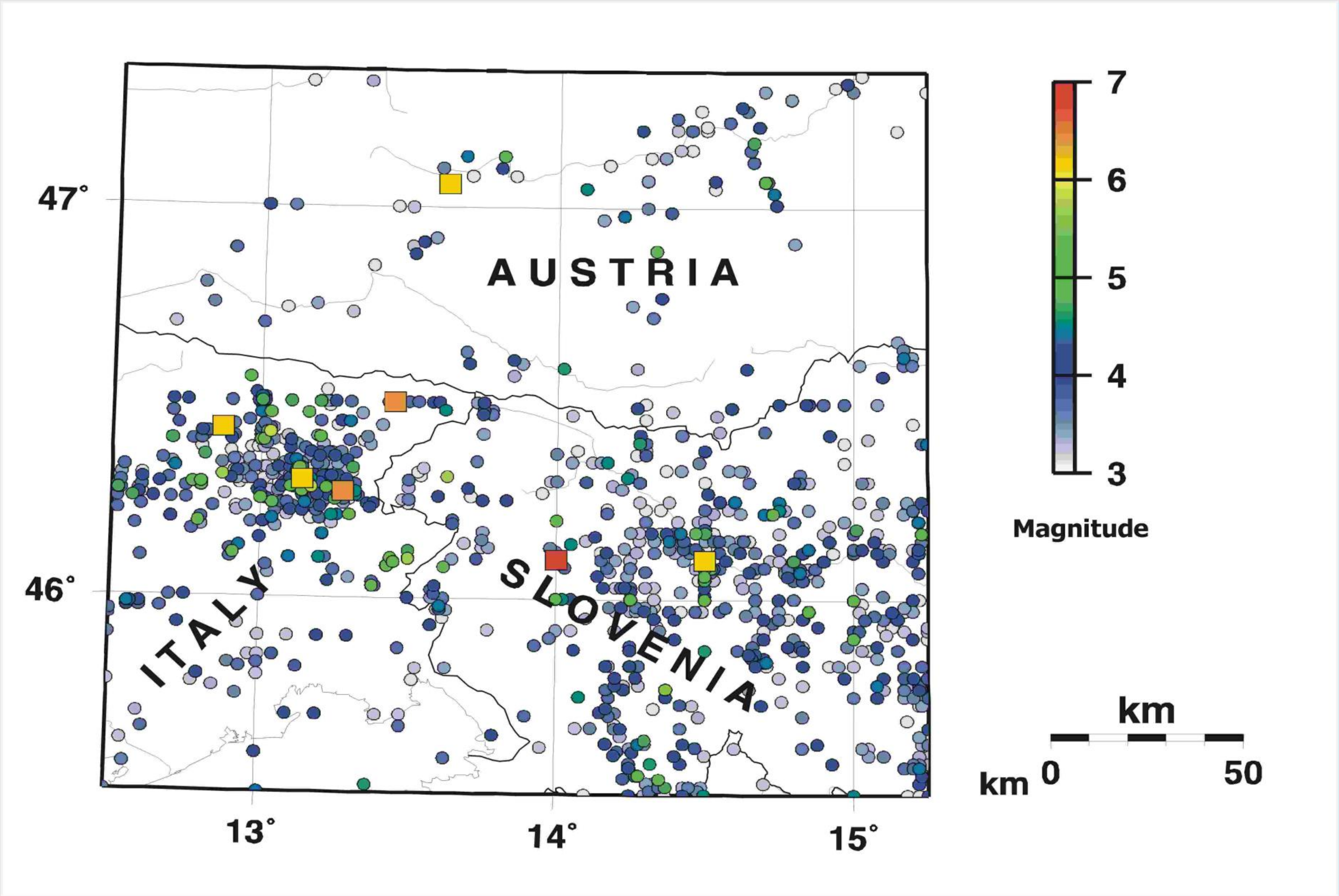

10°
11°
12°
13°
14°
15°
16°
17°
49°
48°
47°
46°
45°
FRIULI VENEZIA GIULIA ACCELEROMETRIC NETWORK (DMG)
NE ITALY BROADBAND NETWORK (OGS/DMG)
SEISMIC NETWORK OF THE REPUBLIC OF SLOVENIA (ARSO)
SEISMIC NETWORK OF AUSTRIA (ZAMG)
SEISMIC NETWORK OF CROATIA (UNIV. ZAGREB)
FRIULI VENETO SP NETWORK (OGS)
SOUTH TYROL BB NETWORK (PROV. BZ)
HAREIA PROJECT ACCELEROMETRIC STATIONS



TCP/IP based data collection system for real time data and triggered data
Field station
Dial up PPP
Modem
Digitizer
RS232
Bridge
RS232 to TCP/IP
Field station
Internet and/or local area network
Router
Modem
Router
ISDN
Dial up connection
Router
Modem
Router
Modem
Router
ISDN
Router
ISDN
Local area network
Field station
Field station
Network
Windows
Field station
Broad band
Linux
Field station
Field station
Sensors
Sensors
Sensors


ARSA HHZ
CEY HHZ
CRES HHZ
LJU HHZ
OBKA HHZ
TRI HHZ
CIMO BHZ
CUSI BHZ
VINO BHZ
GEPF HGZ
STOL HGZ
BAD SHZ
BUA SHZ
CAE SHZ
COLI SHZ
CSM SHZ
CSO SHZ
DRE SHZ
FAU SHZ
LSR SHZ
MLN SHZ
MPRI SHZ
PLRO SHZ
10:54:20.000 2002332
10:54:40.000 2002332
10:55:00.000 2002332
10:55:20.000 2002332
10:55:40.000 2002332
10:56:00.000 2002332
10:56:20.000 2002332
10:56:40.000 2002332

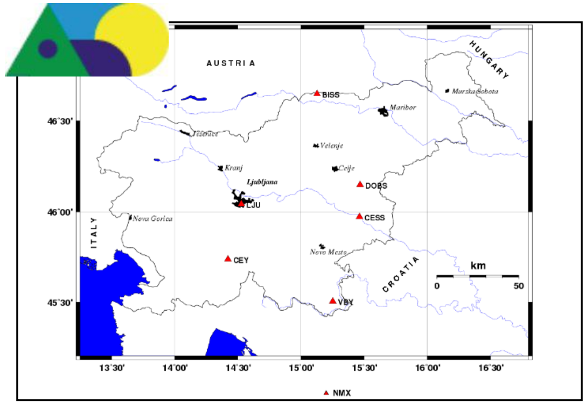
Sismicità storica alpi sud-orientali

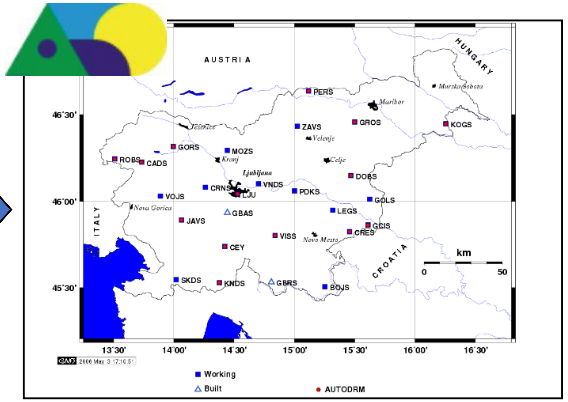


Monitoraggio sismica transfrontaliero

BOVEC 1998

Živčić, (Susans, 2007)





ACCORDO INTERNAZIONALE PER LO SCAMBIO DATI SISMOLOGICI IN "TEMPO-REALE" NELLA REGIONE ALPE-ADRIA

MEDNARODNI SPORAZUM O IZMENJAVI SEIZMOLOŠKIH PODATKOV V "REALNEM ČASU" NA PODROČJU ALPE-JADRAN

INTERNATIONALE VEREINBARUNG FÜR DEN AUSTAUSCH VON SEISMOLOGISCHEN DATEN IN ECHT-ZEIT IN DER ALPEN-ADRIA REGION

INTERNATIONAL AGREEMENT FOR " REAL TIME" SEISMOLOGICAL DATA EXCHANGE IN THE ALPE-ADRIA REGION

Dipartimento di Scienze della Terra, Università degli Studi di Trieste, Trieste, Italia

Istituto Nazionale di Oceanografia e di Geofisica Sperimentale – OGS, Italia

Agencija Republike Slovenije za okolje, urad za seizmologijo, Ljubljana, Slovenija

Zentralanstalt für Meteorologie und Geodynamik, Hauptabteilung Geophysik, Wien, Österreich

NOVEMBER 2001

THE INTERREG IIIA PROJECTs

"TRANS-NATIONAL SEISMOLOGICAL NETWORK IN THE SOUTH-EASTERN ALPS"

FASTLINK

HAREIA
Historical And Recent Earthquakes in Italy and Austria

Trans-National Seismological Networks in the South-Eastern Alps

-

CE3RN

BOVEC 2004

Trans-National Seismological DATABASE

2003-2015

Rete Accelerometrica Nazionale

> 500 stations

- RAN - Syscom
- RAN - Kinemetrics
- RAN - CESI
- RAF
- ISNet

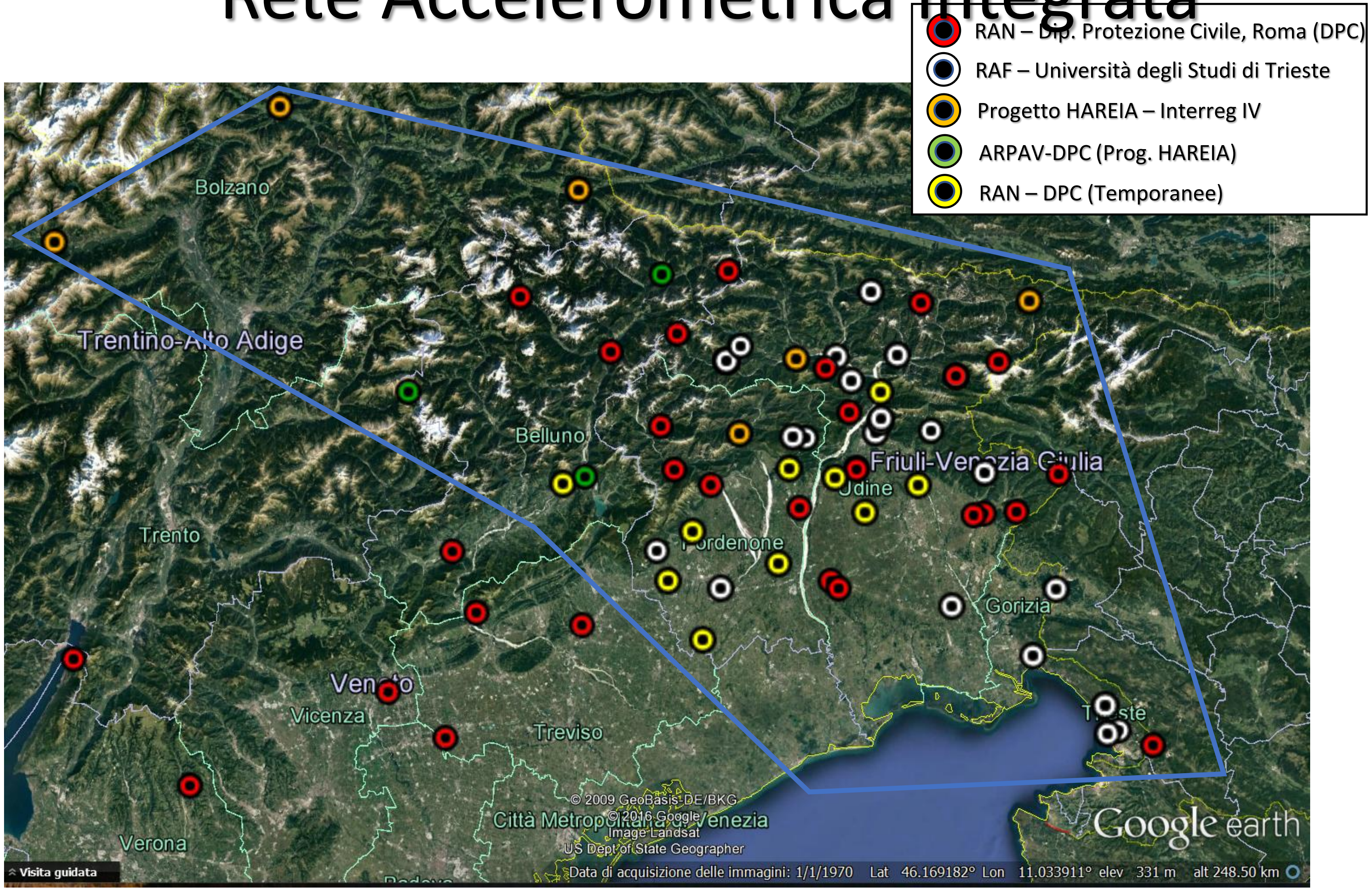
Friuli Venezia Giulia
Accelerometric Network – RAF

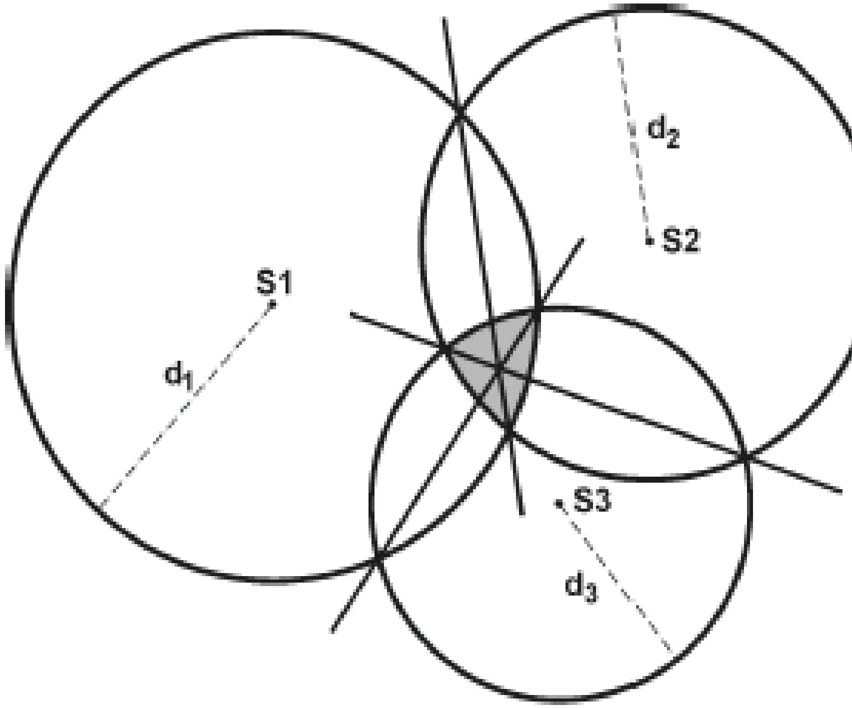
SeisRaM

Irpinia
Seismic Network – ISNET

ISNet

Rete Accelerometrica Integrata



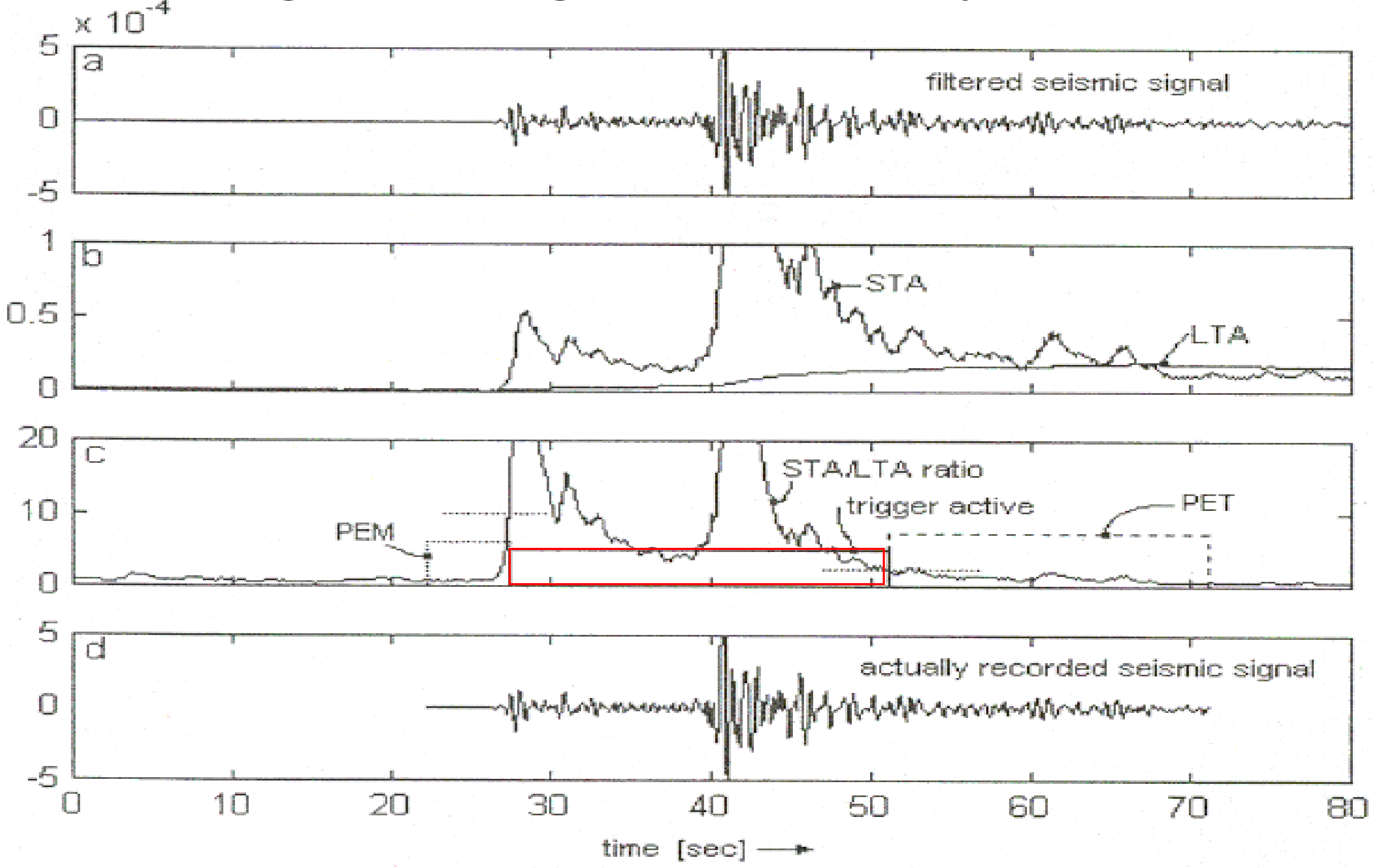


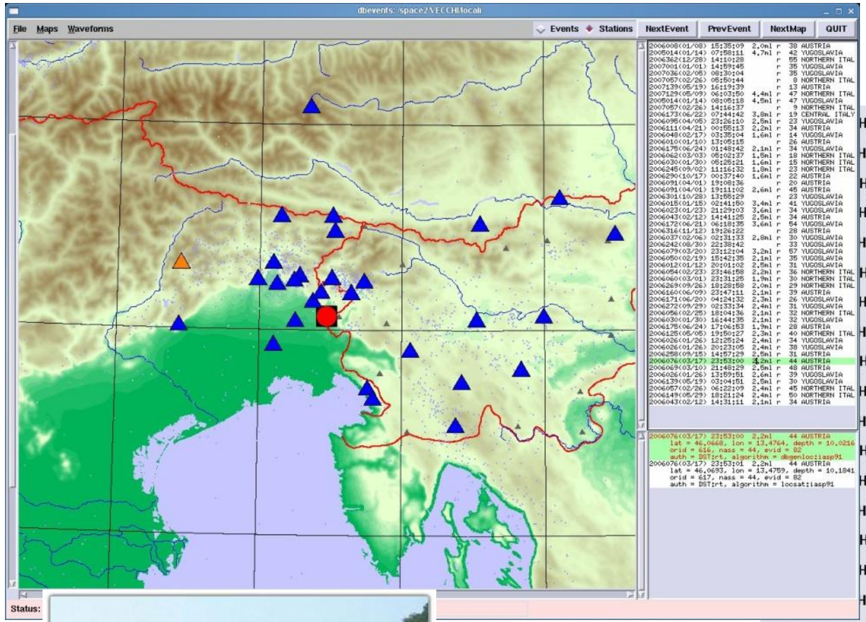
$$d_i = \frac{V_P V_S}{V_P - V_S}\left(t_S - t_P\right)$$

Per determinare l’epicentro di un evento nel caso di velocità V_P e V_S siano conosciute nell’area e si abbiano a disposizione i tempi di arrivo delle onde P ed S a tre stazioni, si può calcolare la distanza d_i dell’evento d aogni stazione e determinare l’epicentro.

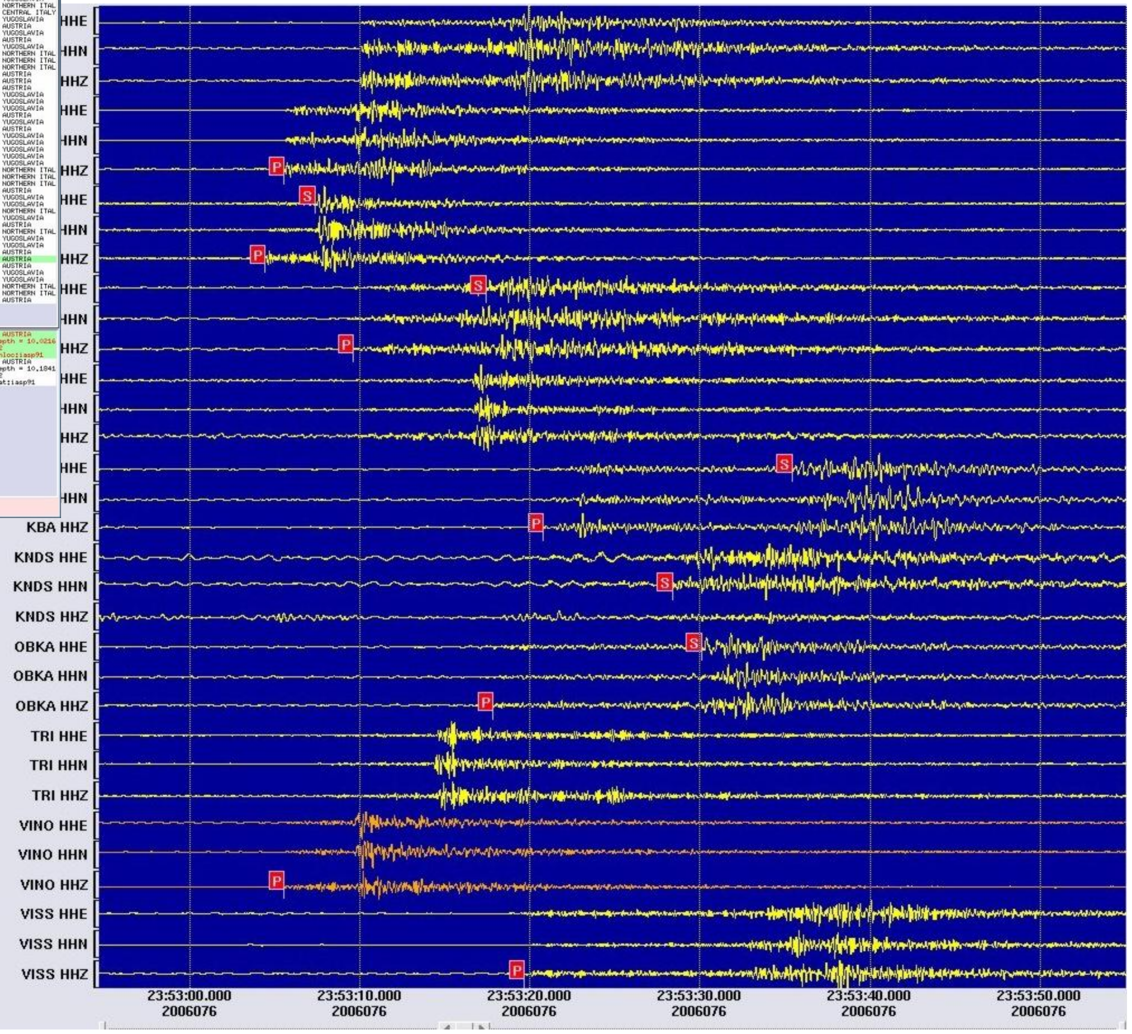
STA – short time average
LTA – long time average

PEM – Pre-event time
PET - post event time




File Maps Waveforms
Events Stations
NextEvent PrevEvent NextMap QUIT
Status:


PROTEZIONE CIVILE
zivilschutz
protection civile
civil defence


HHE
HHN
HHZ
KBA HHZ
KNDS HHE
KNDS HHN
KNDS HHZ
OBKA HHE
OBKA HHN
OBKA HHZ
TRI HHE
TRI HHN
TRI HHZ
VINO HHE
VINO HHN
VINO HHZ
VISS HHE
VISS HHN
VISS HHZ
23:53:00.000 2006076
23:53:10.000 2006076
23:53:20.000 2006076
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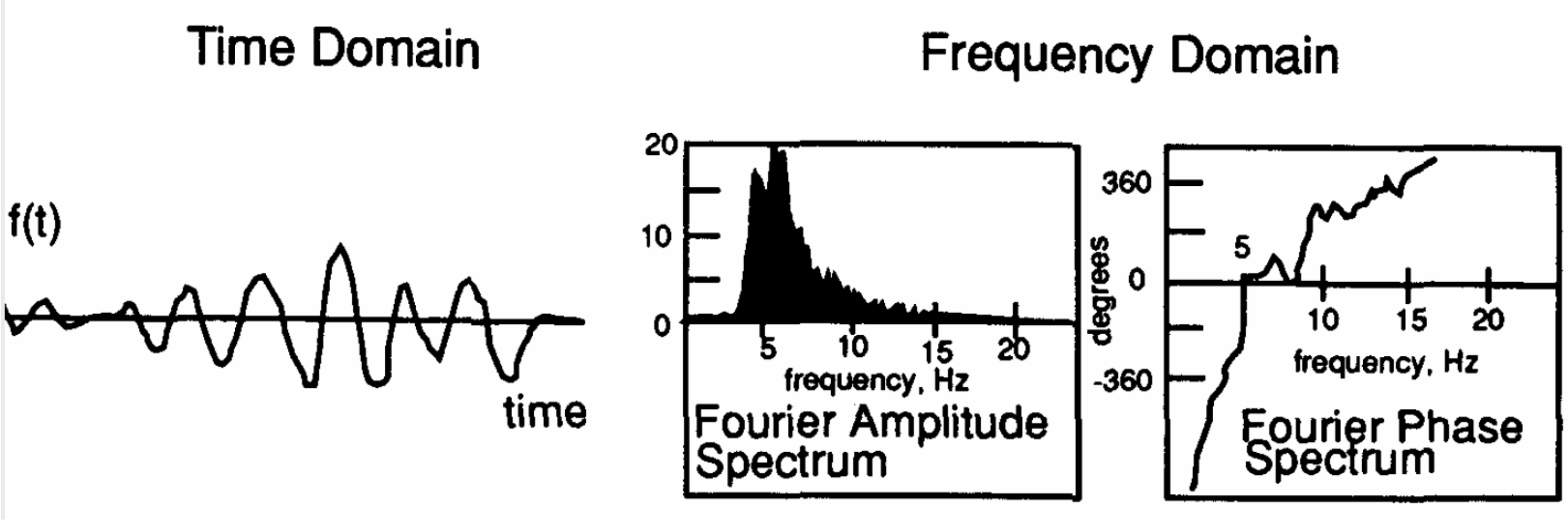
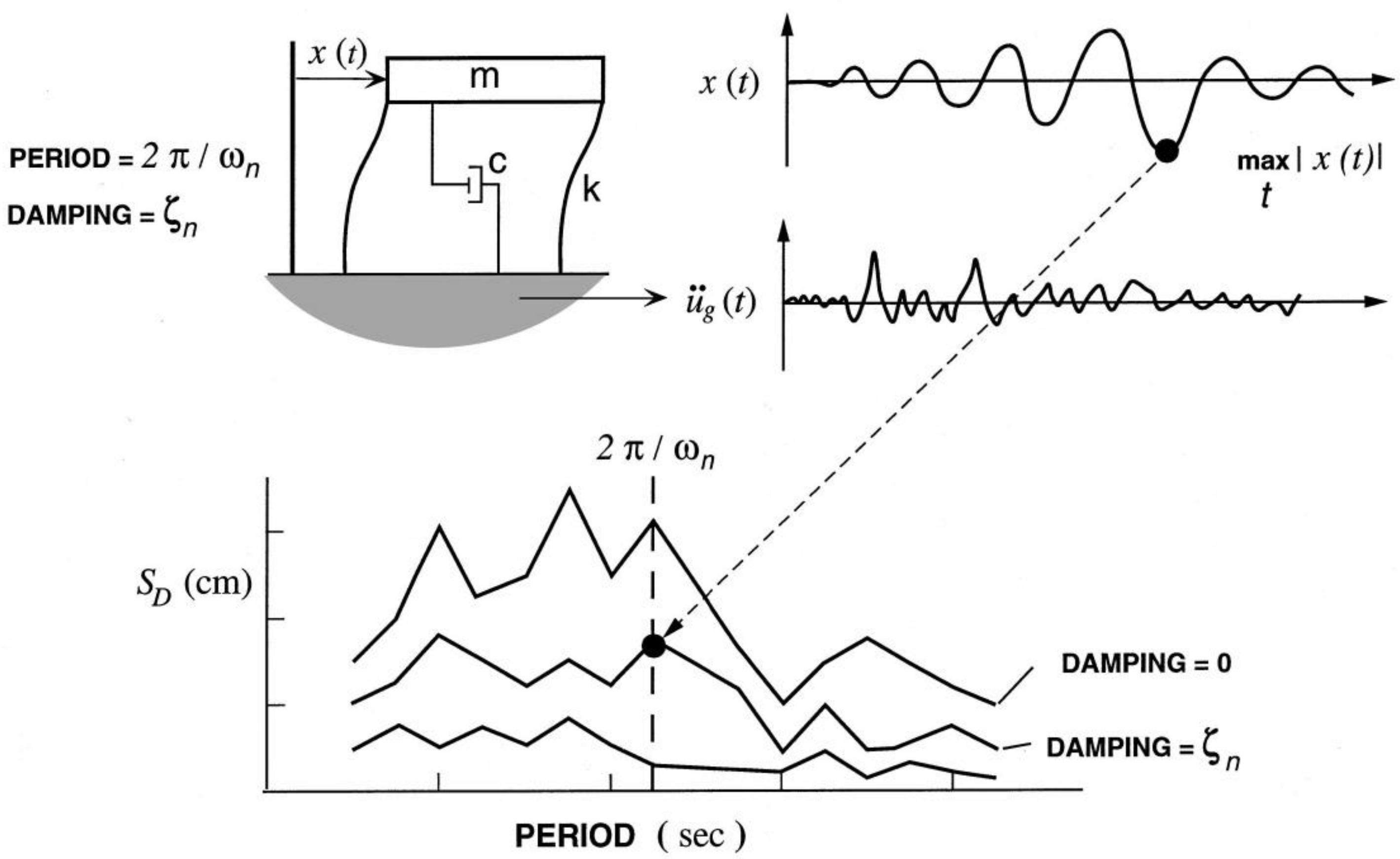
23:53:50.000 2006076



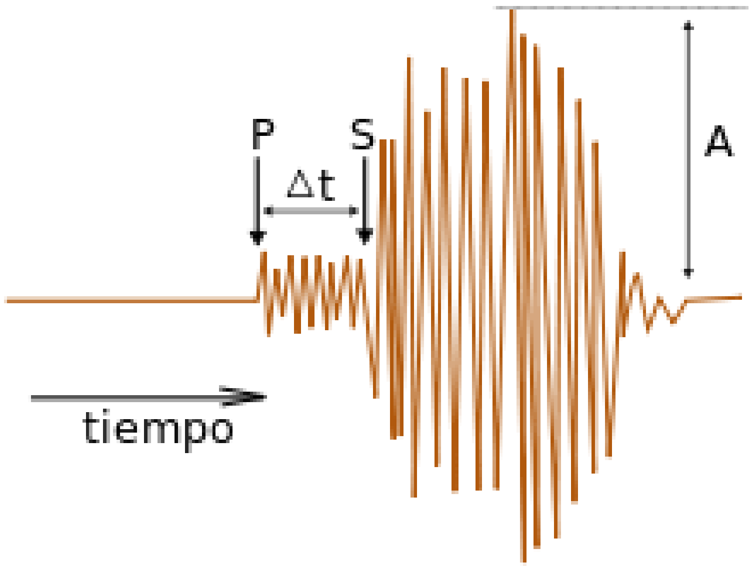
Un segnale registrato in funzione del tempo (a sinistra) può essere rappresentato in modo equivalente nel dominio delle frequenza dal suo spettro di Fourier. L'ampiezza (in centro) e lo spettro di fase (a destra) sono entrambi necessari per ottenere la serie temporale completa.

SPETTRI DI RISPOSTA



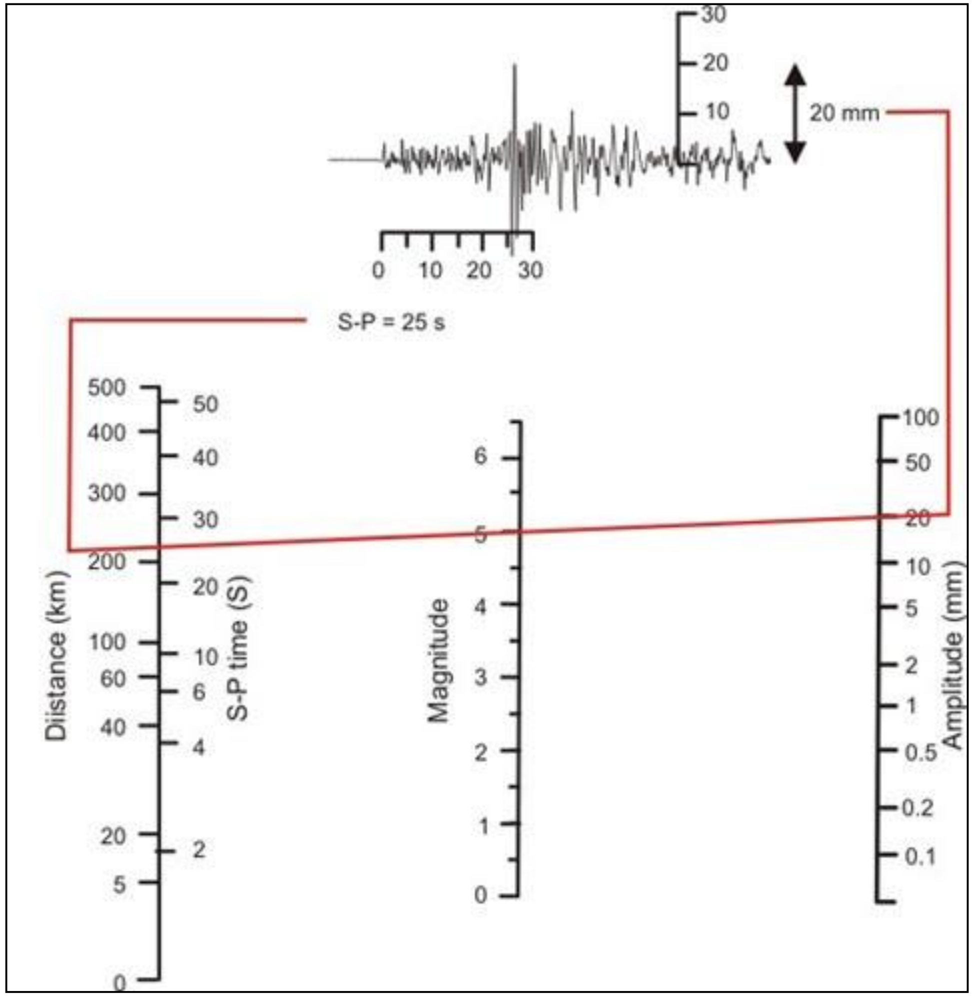
Magnitudo

La ***magnitudo***, più propriamente, è un parametro atto a rappresentare l'energia sprigionata da un terremoto. Viene calcolata sulla base di misure effettuate sul sismogramma, maggiore è l'energia liberata dal sisma maggiori sono le ampiezze delle oscillazioni registrate. Misurata per molti anni (simbolo M) tramite la Scala Richter, oggi esistono diverse scale di magnitudo. Tutte le scale, a differenza della Scala Mercalli, non sono decimali ma *logaritmiche* perciò la differenza di un'unità implica un potenziale energetico di circa *30 volte maggiore o minore*.



$$\boxed{M = \log A / A_0 + \varepsilon}$$

A = ampiezza massima delle oscillazioni del terremoto che si sta osservando
A_0 = ampiezza massima delle oscillazioni causate da un terremoto di riferimento
ε = fattore di correzione (distanza reale dall'epicentro, profondità dell'ipocentro)



Procedure for calculating the local magnitude, M_L

1. Measure the distance to the focus using the time interval between the S and the P waves (S − P = 24 seconds).
2. Measure the height of the maximum wave motion on the seismogram (23 millimeters).
3. Place a straight edge between appropriate points on the distance (left) and amplitude (right) scales to obtain magnitude M_L = 5.0.

$$M_L = log_{10}(A) - log_{10}(\Delta) \qquad [Eq\ 3]$$

General form of Magnitude scales:

$$M = \log(A/T) + F(h, \Delta) + C$$

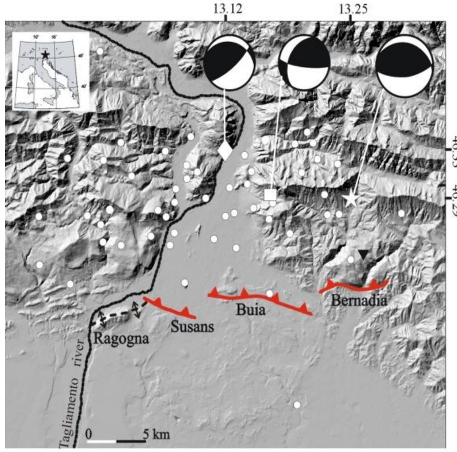
A is the amplitude of the signal

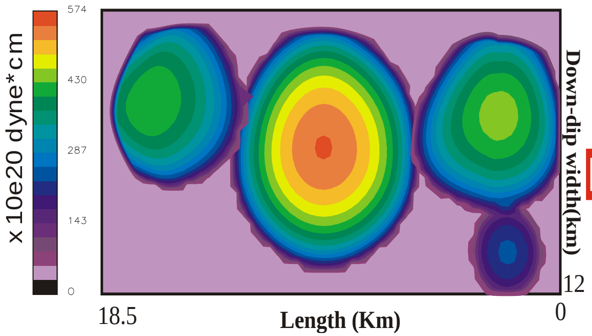
T is its dominant period

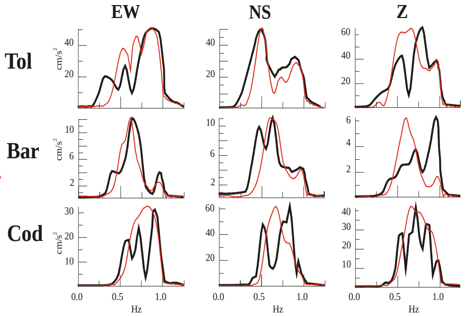
F is a correction for the variation of amplitude with the earthquake's depth h and distance Δ from the seismometer

C is a regional scale factor

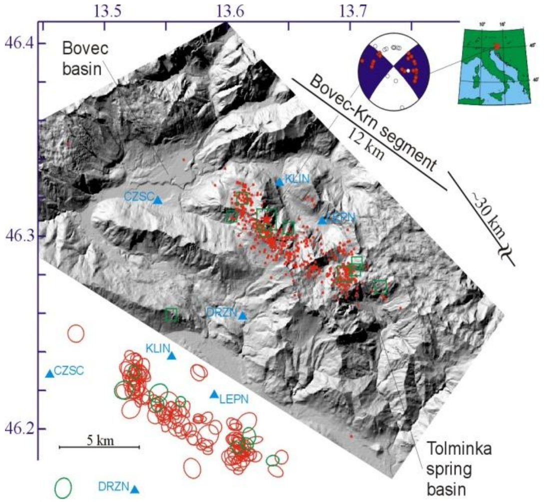
Fault slip models: the1976 and 1998 main shocks

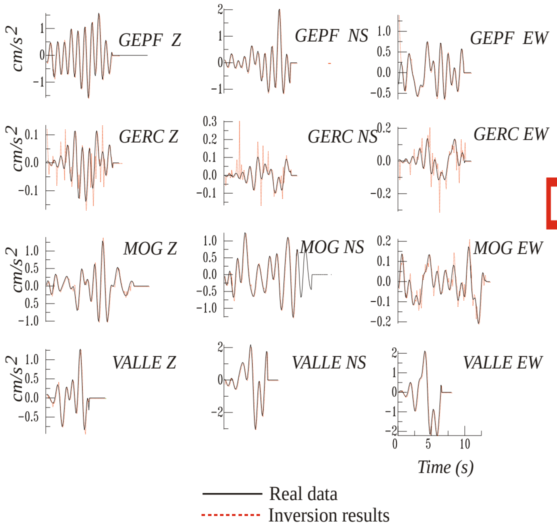


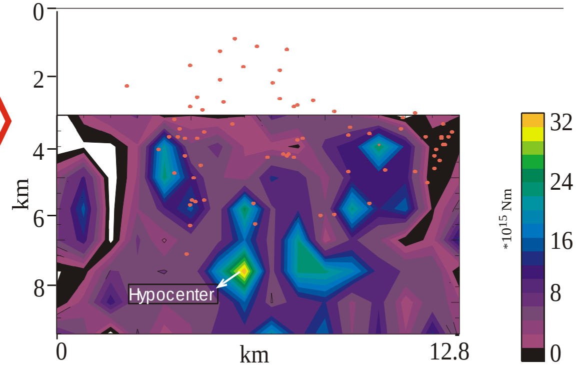




Aoudia et al., GRL, 2000

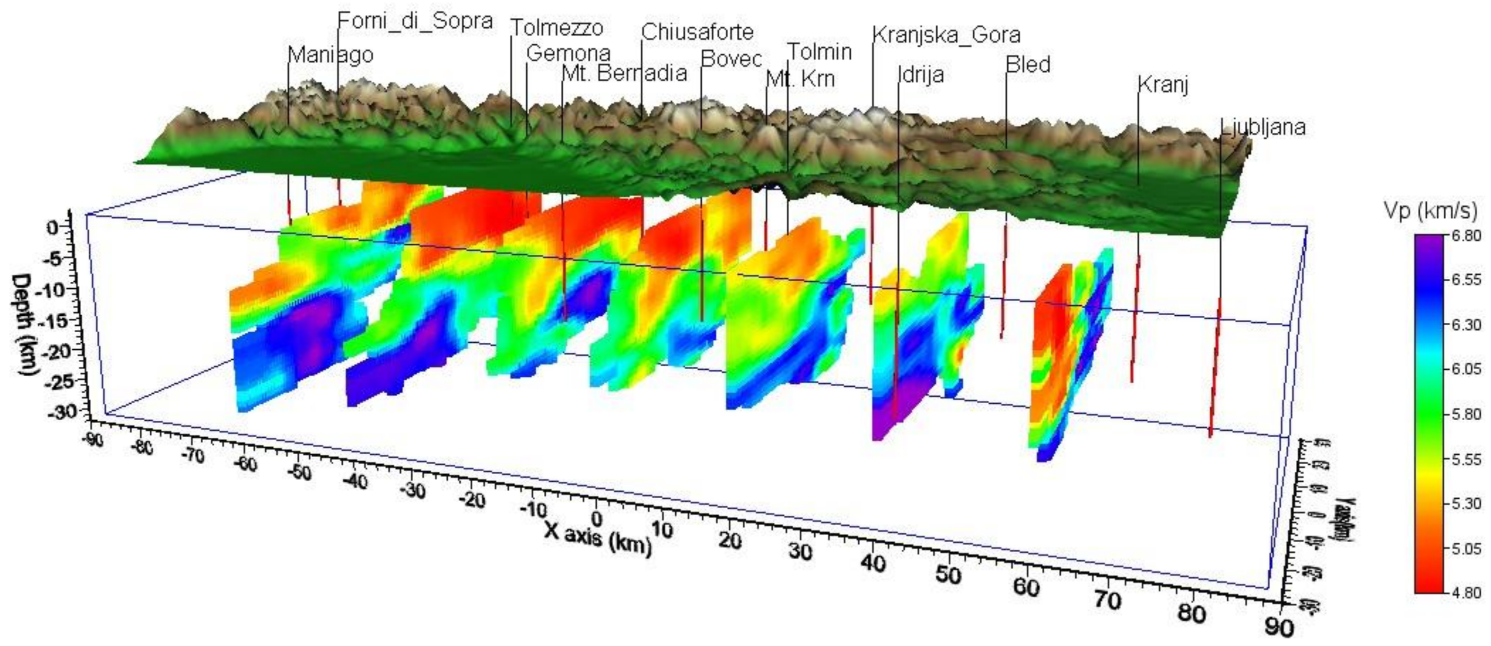






Bajc, et al. GRL, 2001

Tomografia



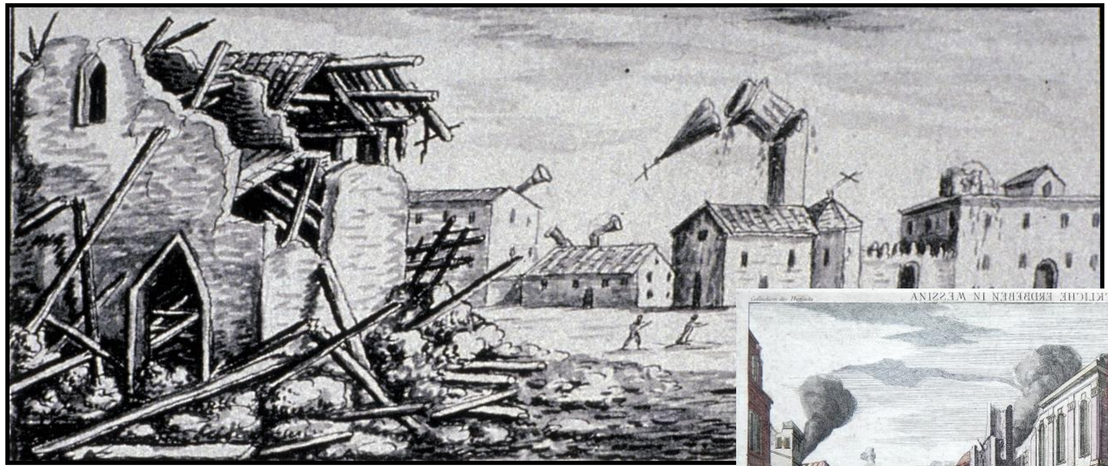
Forni_di_Sopra
Tolmezzo
Chiusaforte
Kranjska_Gora
Maniago
Gemona
Bovec
Tolmin
Bled
Mt. Bernadia
Mt. Krn
Idrija
Kranj
Ljubljana
Depth (km)
X axis (km)
Y axis (km)
Vp (km/s)
6.80
6.55
6.30
6.05
5.80
5.55
5.30
5.05
4.80

Intensità

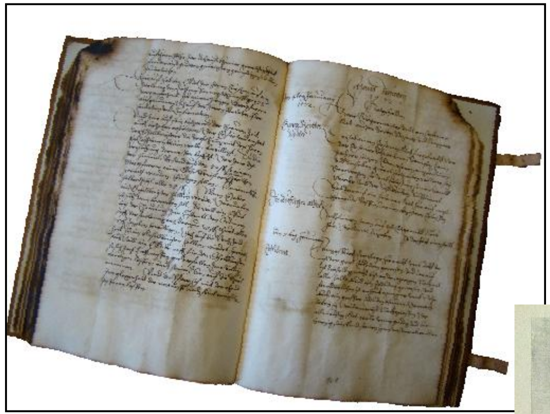
- Misura gli effetti di un terremoto sulle persone, sugli edifici e sul territorio.

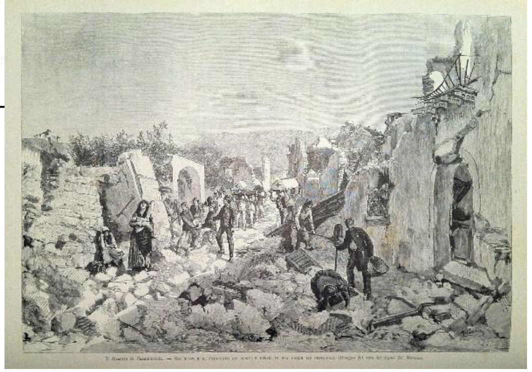
SCALA MERCALLI		
I	- Strumentale	Avvertita solo dagli strumenti
II	- Debole	Avvertita solo da poche persone sensibili in condizioni particolari
III	- Leggera	Avvertita da poche persone
IV	- Moderata	Avvertita da molte persone; tremiti di infissi e cristalli; oscillazione di oggetti sospesi
V	- Piuttosto forte	Avvertita da molte persone, anche addormentate; caduta di oggetti
VI	- Forte	Qualche lesione agli edifici
VII	- Molto forte	Caduta di comignoli; lesione agli edifici
VIII	- Distruttiva	Rovina parziale di alcuni edifici; vittime isolate
IX	- Rovinosa	Rovina totale di alcuni edifici; molte vittime; crepacci nel suolo
X	- Disastrosa	Crollo di parecchi edifici; numerevoli vittime; crepacci evidenti nel terreno
XI	- Molto disastrosa	Distruzione di agglomerati urbani; moltissime vittime; crepacci; frane; maremoto
XII	- Catastrofica	Danneggiamento totale; distruzione di ogni manufatto; pochi superstiti; sconvolgimento del suolo; maremoto

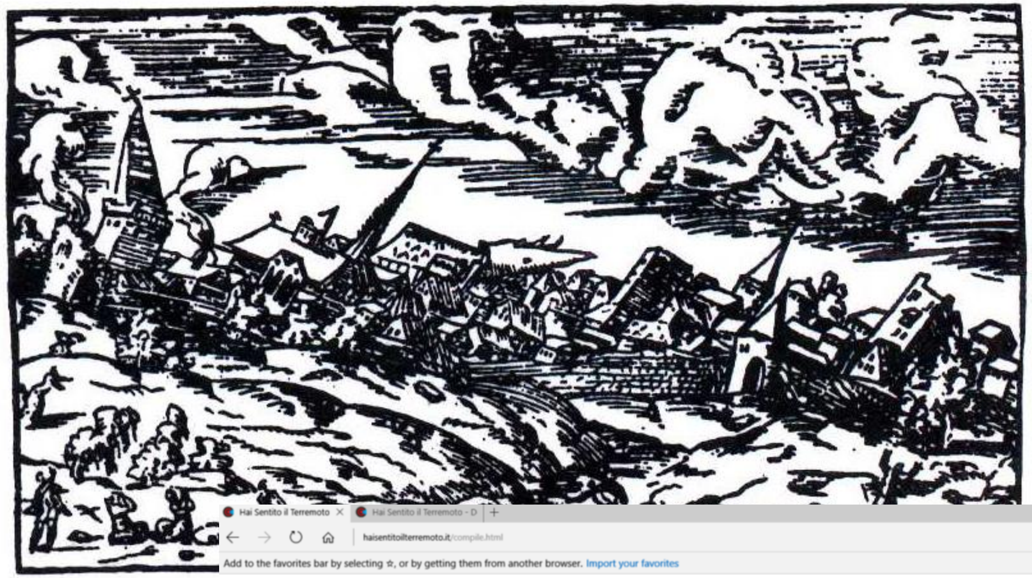
Intensità

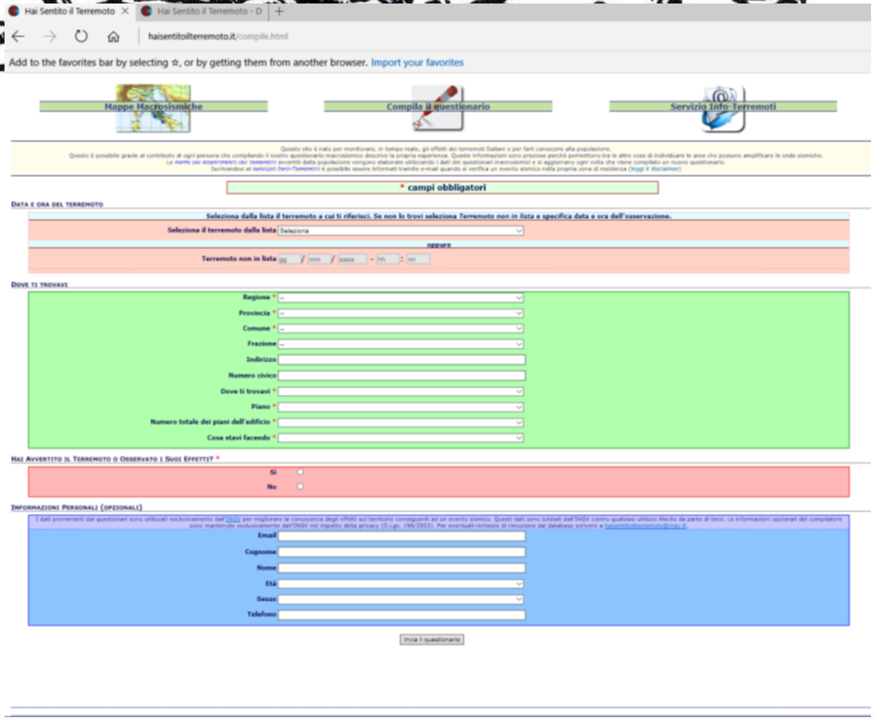



Das erschröckliche Erdbeben in Messina
Le terrible tremblement de terre à Messine

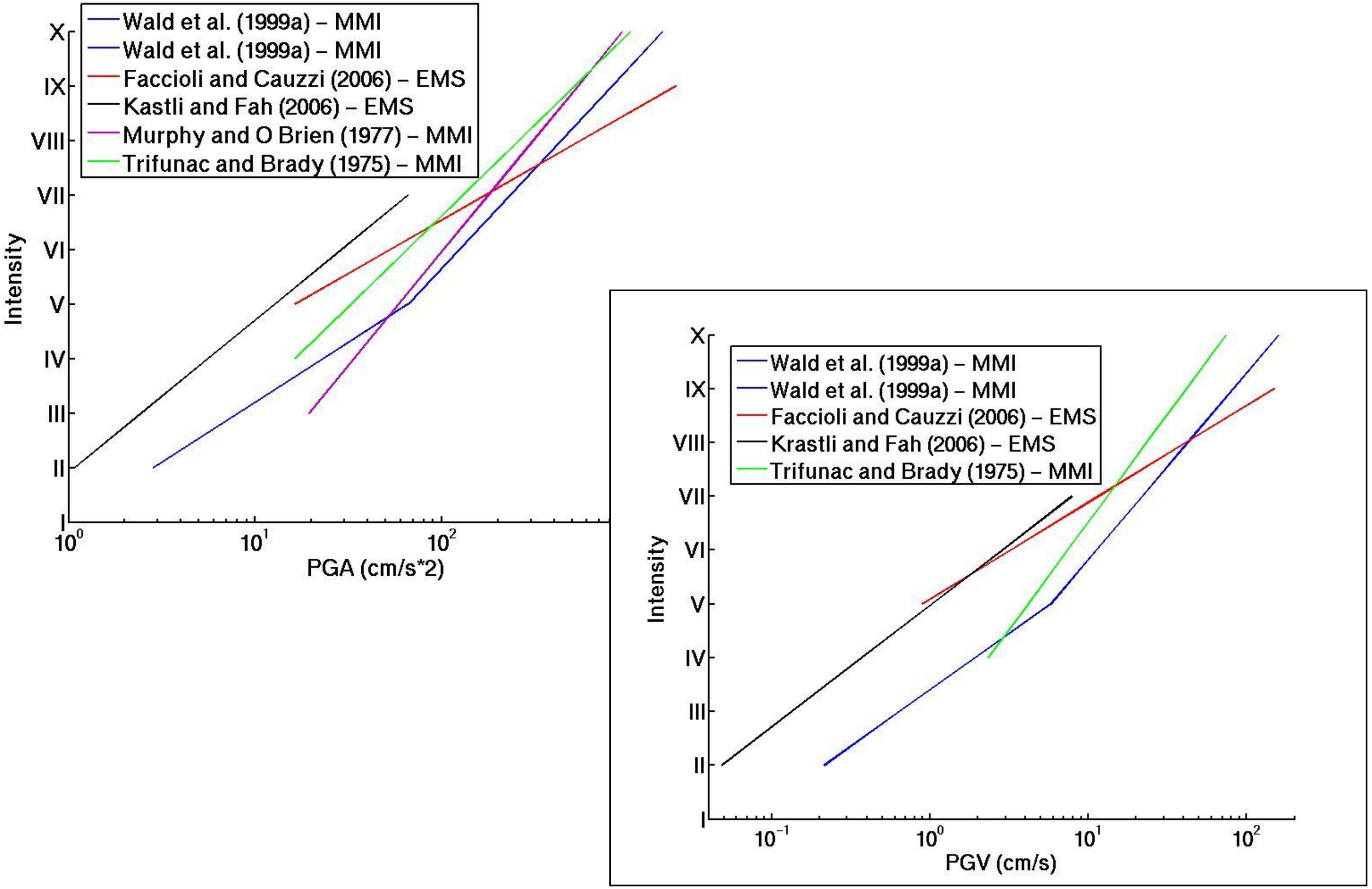







Hai Sentito il Terremoto
haisentitoilterremoto.it/compile.html
Add to the favorites bar by selecting ☆, or by getting them from another browser. Import your favorites
Mappe Macrosismiche
Compila il questionario
Servizio Info-Terremoti
* campi obbligatori

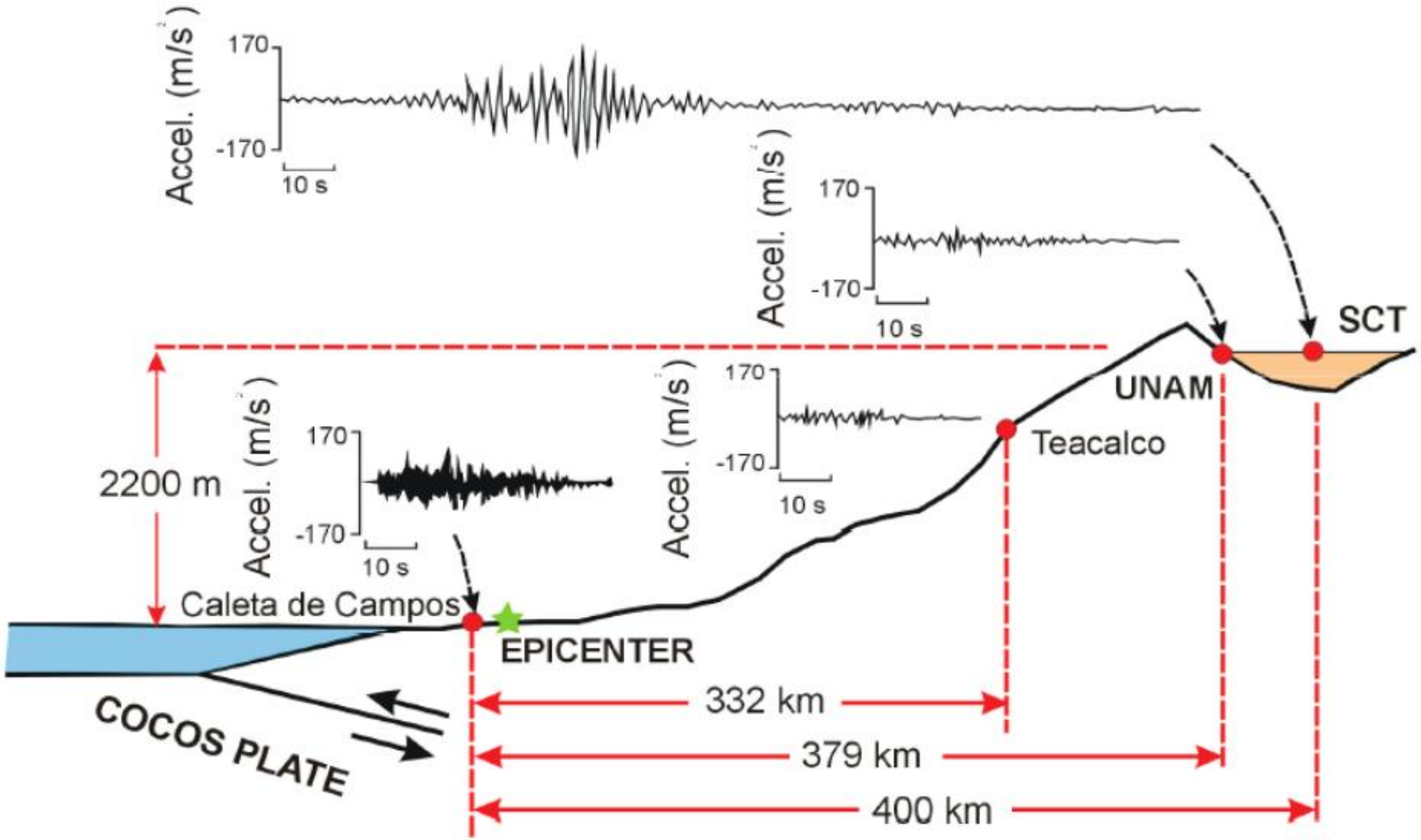
Relazioni PGA/PGV – Intensità



sta	chan	dista km	filter Hz	PGA cm/s*s	EPA cm/s*s	PGV cm/s	PGD cm	PSA03 cm/s*s	PSA10 cm/s*s	PSA30 cm/s*s	EC8	location
NRC	HGE	12	0.2-50.0	242.42	172.05	19.01	2.00	357.42	174.66	16.34	B	Norcia
NRC	HGN	12	0.2-50.0	346.88	269.93	19.96	1.74	398.15	105.84	30.85	B	Norcia
NRC	HGZ	12	0.2-50.0	211.46	134.60	8.75	1.09	275.52	63.99	12.05	B	Norcia
RQT	HGE	18	0.2-50.0	188.81	115.67	5.36	0.77	169.52	49.68	9.30	B*	Arquata_Del_Tronto
RQT	HGN	18	0.2-50.0	147.80	109.77	5.64	1.03	255.30	64.97	14.20	B*	Arquata_Del_Tronto
RQT	HGZ	18	0.2-50.0	116.17	50.55	3.98	0.90	113.45	41.83	14.39	B*	Arquata_Del_Tronto
MNF	HGE	19	0.2-50.0	128.04	81.35	8.36	1.61	178.54	68.11	10.65	A*	MonteFiegni-Fiastra
MNF	HGN	19	0.2-50.0	87.18	81.19	7.64	2.33	195.07	123.40	30.46	A*	MonteFiegni-Fiastra
MNF	HGZ	19	0.2-50.0	98.35	68.07	5.77	2.55	180.01	81.65	26.25	A*	MonteFiegni-Fiastra
CSC	HGE	22	0.2-50.0	70.02	53.03	3.63	0.95	109.97	47.65	13.34	B	Cascia
CSC	HGN	22	0.2-50.0	68.86	40.81	3.25	0.82	93.76	65.26	14.69	B	Cascia
CSC	HGZ	22	0.2-50.0	39.76	31.57	2.56	0.75	64.54	21.66	12.66	B	Cascia
CLF	HGE	22	0.2-50.0	122.01	91.70	11.04	1.85	259.34	237.60	13.97	D	Colfiorito_Casone
CLF	HGN	22	0.2-50.0	155.64	122.26	13.69	2.57	264.80	357.05	18.22	D	Colfiorito_Casone
CLF	HGZ	22	0.2-50.0	82.97	81.19	5.35	1.02	106.22	74.43	7.38	D	Colfiorito_Casone
FOC	HGE	23	0.2-50.0	606.13	477.17	19.60	0.90	1252.98	47.27	7.49	C*	Foligno_Colfiorito
FOC	HGN	23	0.2-50.0	365.33	215.49	9.57	1.10	426.11	56.75	9.40	C*	Foligno_Colfiorito
FOC	HGZ	23	0.2-50.0	169.10	88.95	3.64	0.51	193.81	17.14	6.55	C*	Foligno_Colfiorito
TRE	HGE	31	0.2-50.0	40.25	36.64	2.96	0.86	75.79	39.66	13.70	C*	Trevi
TRE	HGN	31	0.2-50.0	37.69	34.26	2.73	0.50	82.20	36.89	5.80	C*	Trevi
TRE	HGZ	31	0.2-50.0	25.86	20.39	2.13	0.63	53.66	26.59	6.75	C*	Trevi
FOPC	HGE	35	0.2-50.0	32.45	30.05	2.69	0.70	58.73	36.90	10.89	na	Foligno Prot Civ Reg
FOPC	HGN	35	0.2-50.0	31.67	30.28	2.78	0.97	90.06	57.15	11.56	na	Foligno Prot Civ Reg
FOPC	HGZ	35	0.2-50.0	26.51	18.02	1.92	0.49	35.57	29.77	6.73	na	Foligno Prot Civ Reg
SPM	HGE	36	0.2-50.0	75.94	45.17	2.17	0.55	97.51	13.07	5.23	A*	Spoleto_Monteluco
SPM	HGN	36	0.2-50.0	57.39	44.07	1.74	0.69	110.17	11.66	8.12	A*	Spoleto_Monteluco
SPM	HGZ	36	0.2-50.0	23.11	15.26	1.10	0.40	28.21	9.76	6.77	A*	Spoleto_Monteluco
NCR	HGE	36	0.2-50.0	225.76	182.83	7.67	0.64	239.86	42.60	5.65	E	Nocera_Umbra

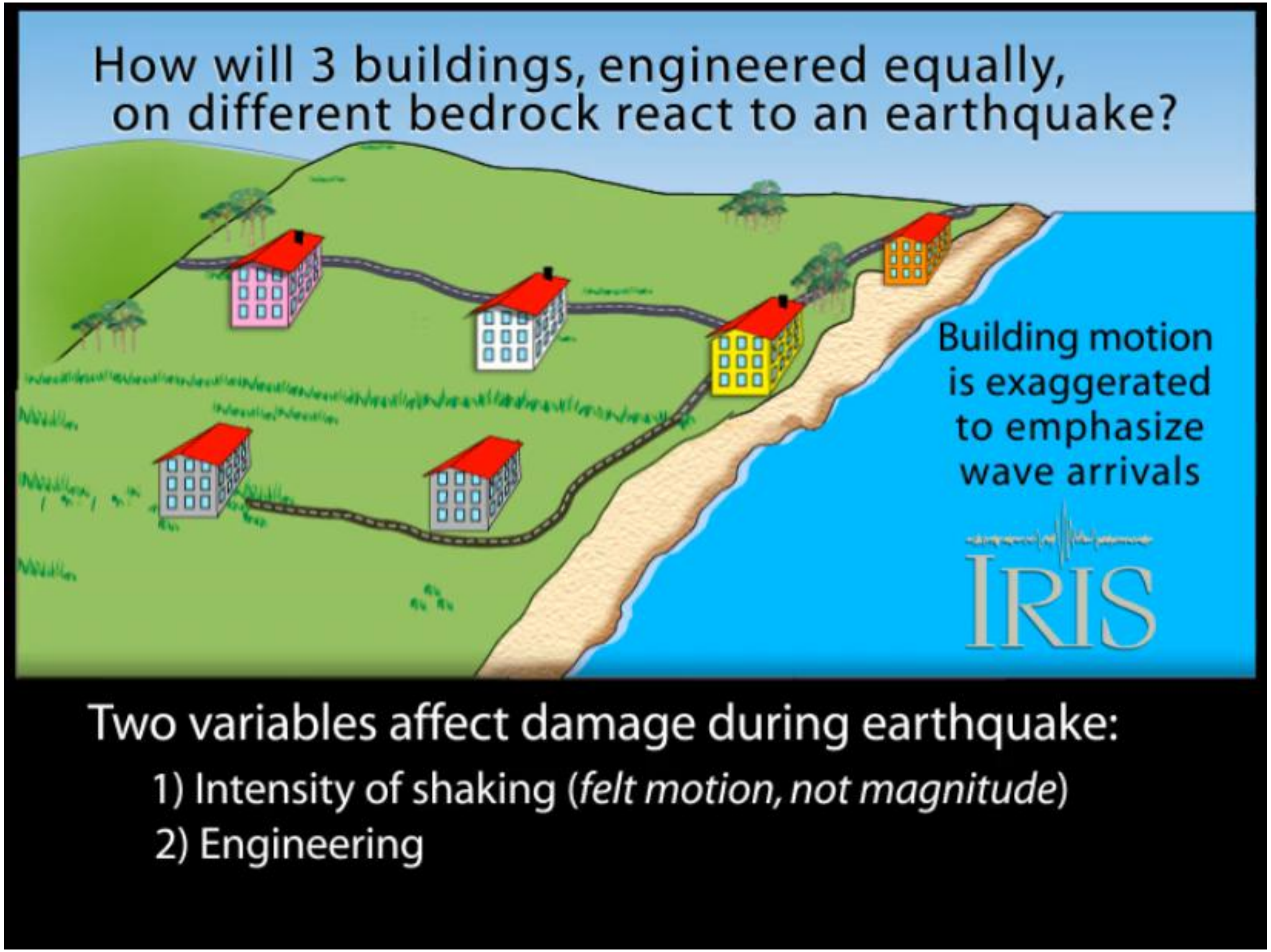
dista = epicentral distance
filter = automatic band pass butterworth filter
EC8 = site classification (Eurocode from ITACA)

PGA,PGV,PGD = peak ground acceleration, velocity and displacement
EPA = effective ground acceleration (Kramer, 1996)
PSA03,PSA10,PSA30 = spectral acceleration (0.3, 1.0, 3.0 sec)



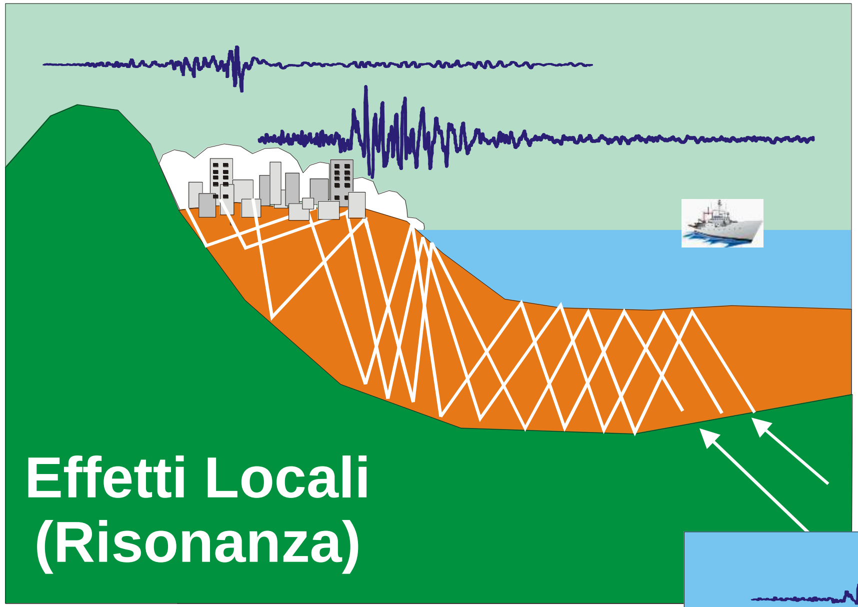
Schema sismogrammi relativi alla citta del Messico che mostrano l'amplificazione del bacino dove sorge Citta del Messico.

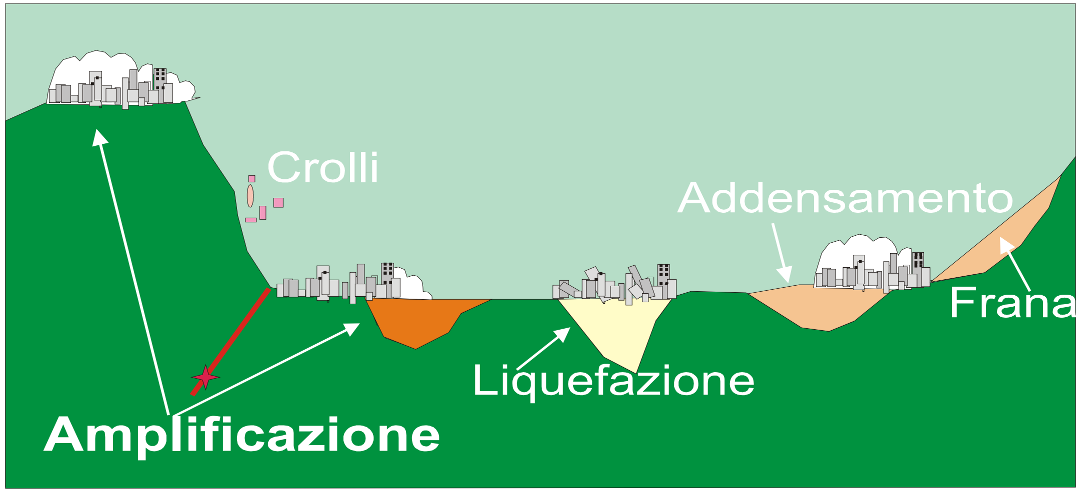
Effetti di sito

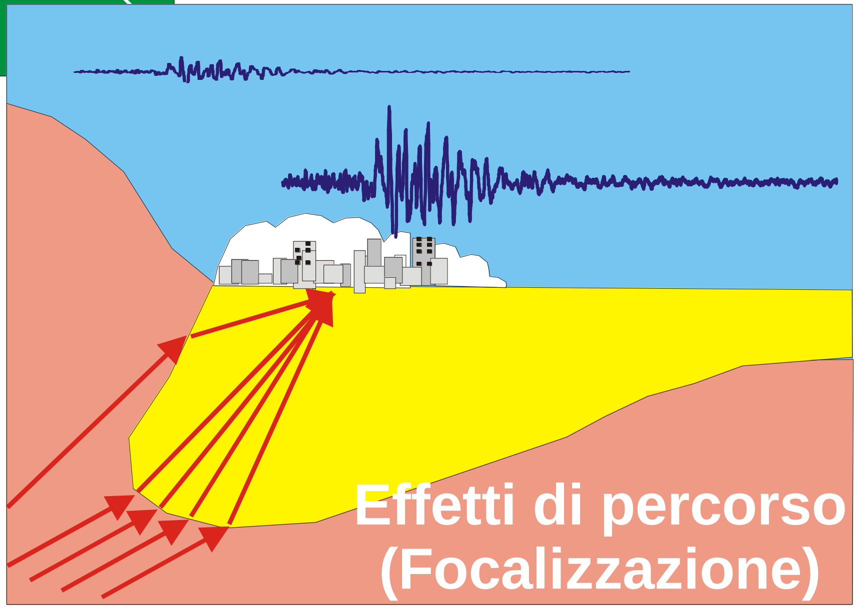


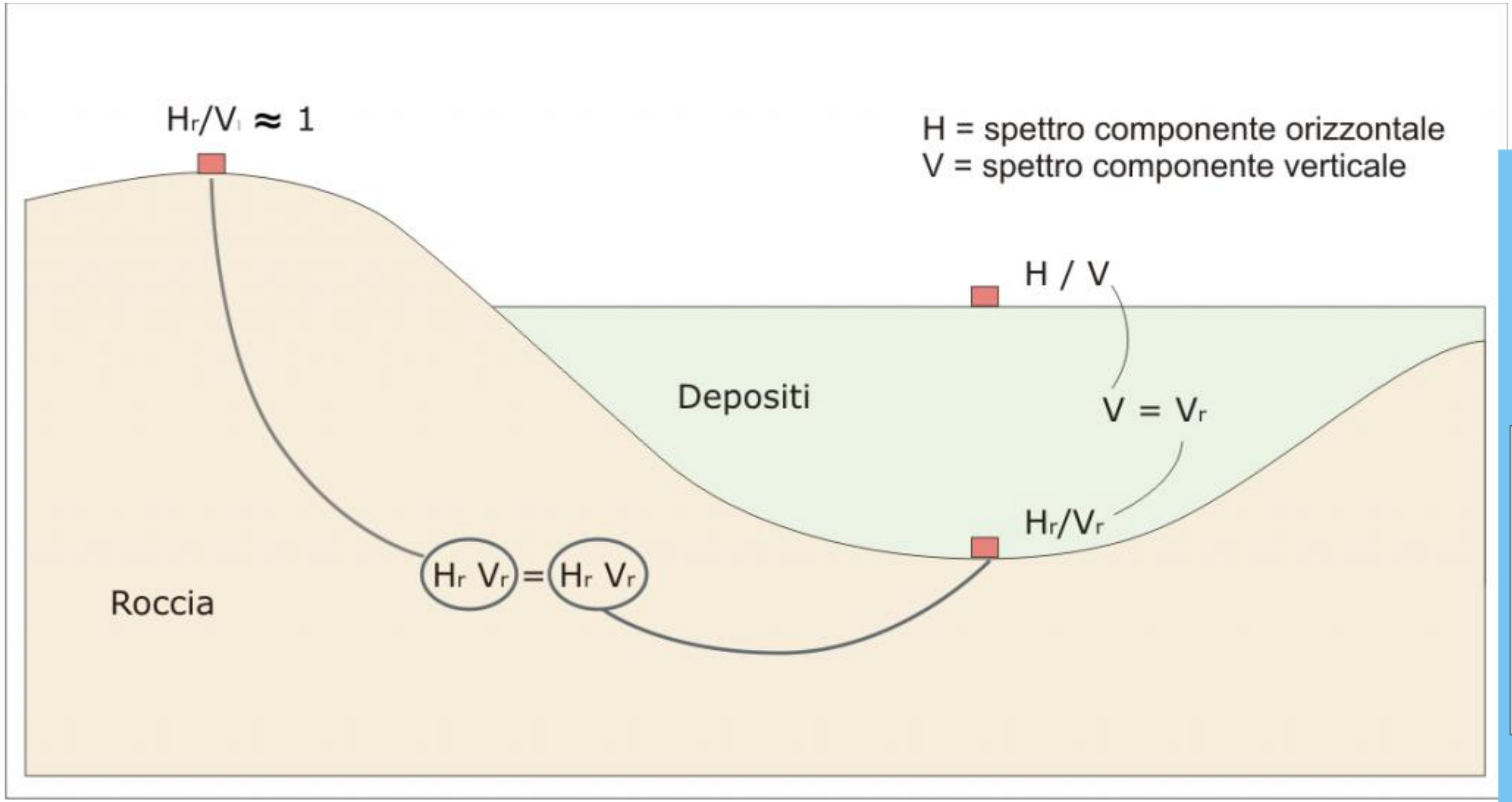
Effetti di sito

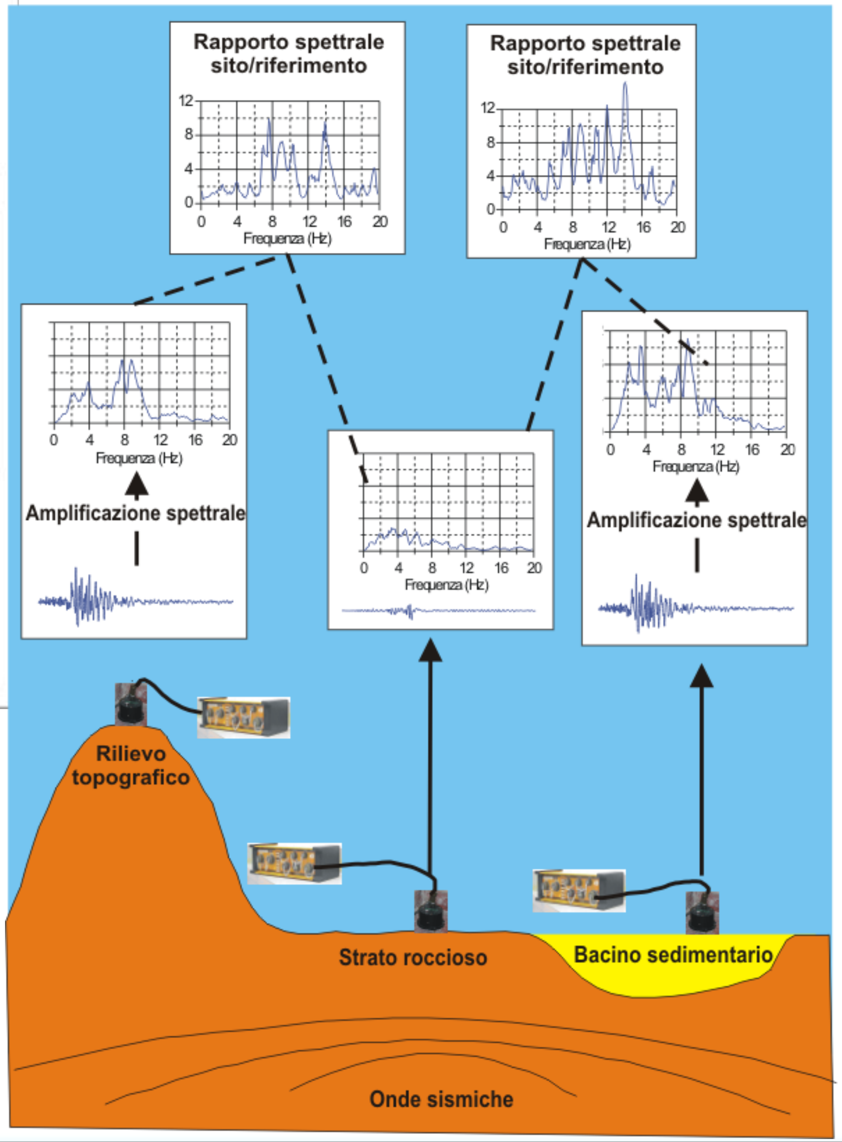
EFFETTI LOCALI INDOTTI DA UN EVENTO SISMICO





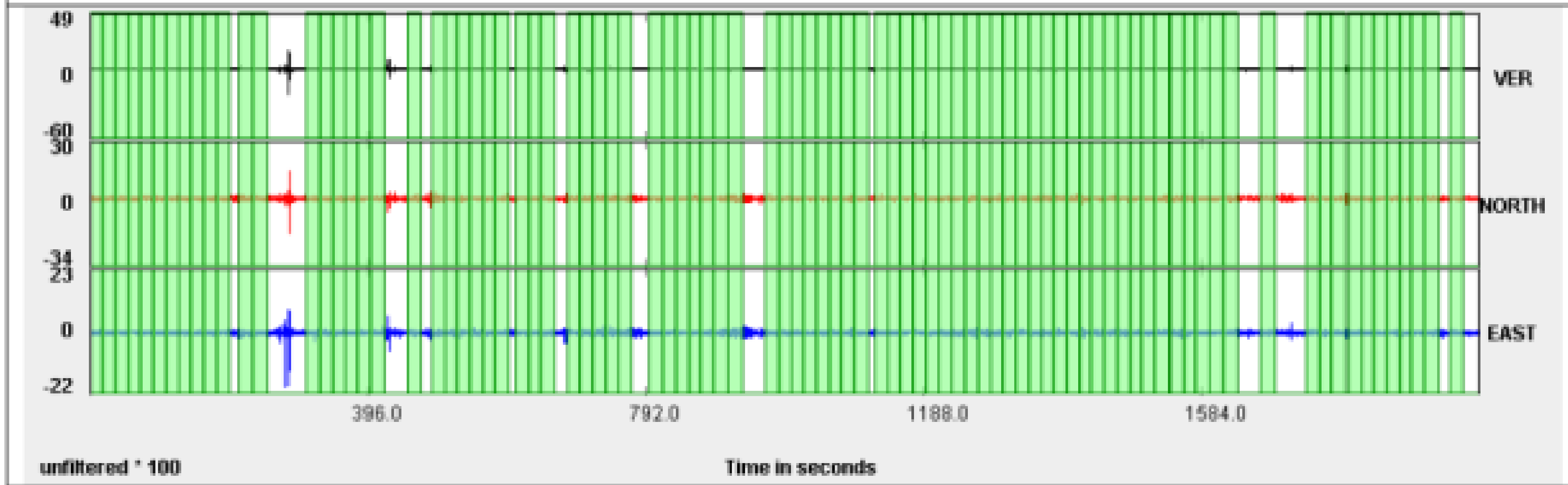




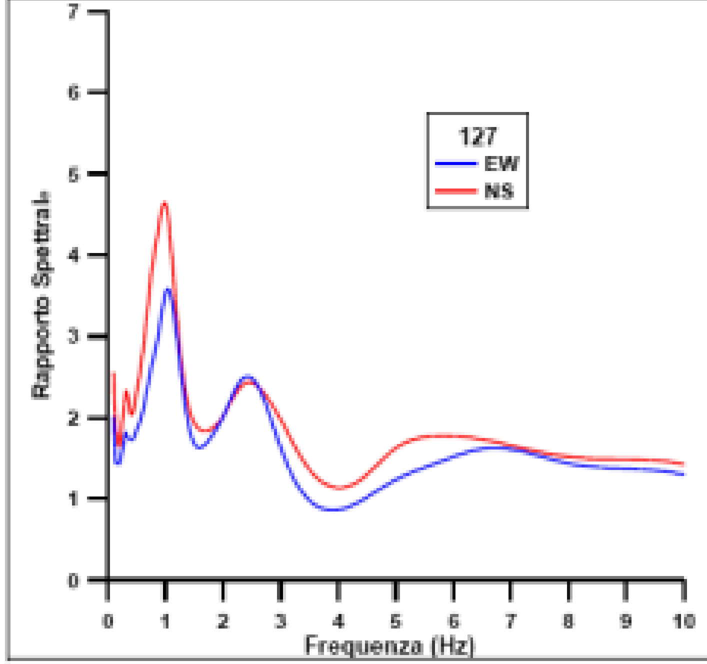


H/V Rapporti spettrali - Nakamura

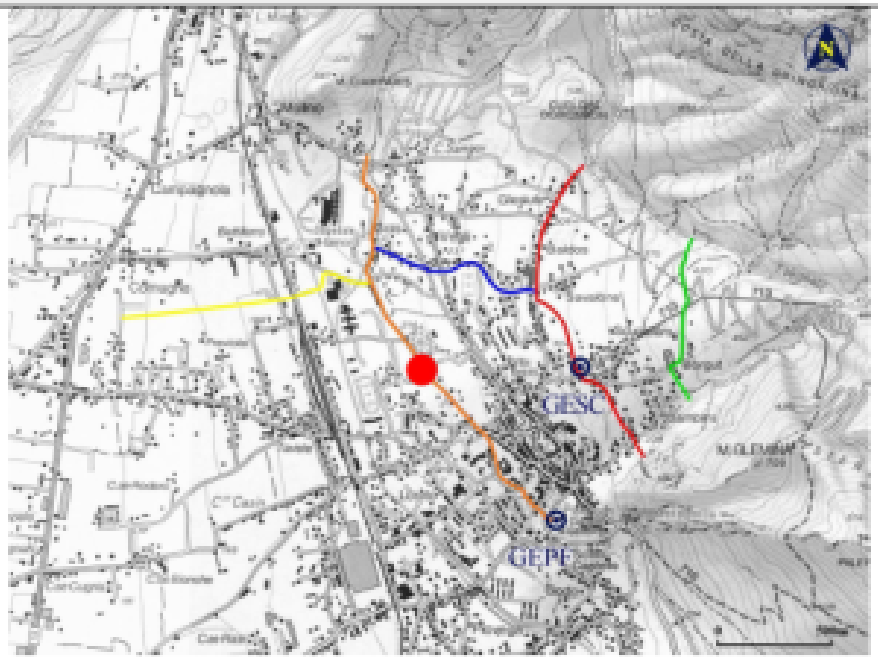
PUNTO 127



49
0
-60
30
0
-34
23
0
-22
VER
NORTH
EAST
396.0
792.0
1188.0
1584.0
unfiltered * 100
Time in seconds

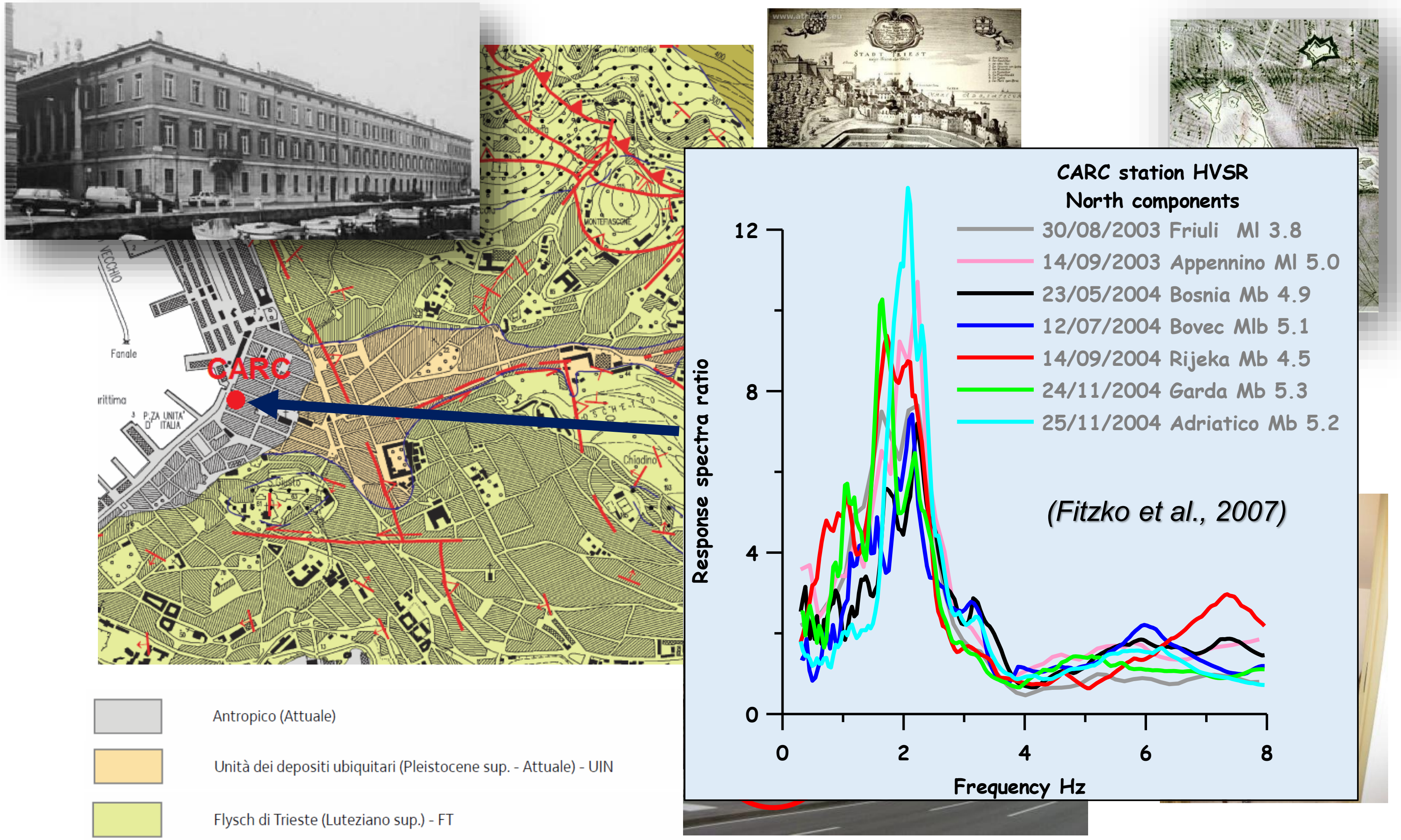


127
EW
NS
Rapporto Spettrale
Frequenza (Hz)
0
1
2
3
4
5
6
7
8
9
10



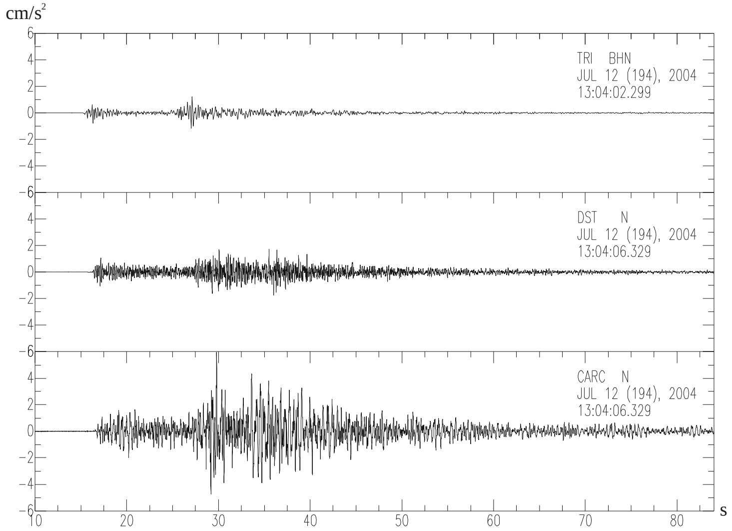
GESC
GEPE

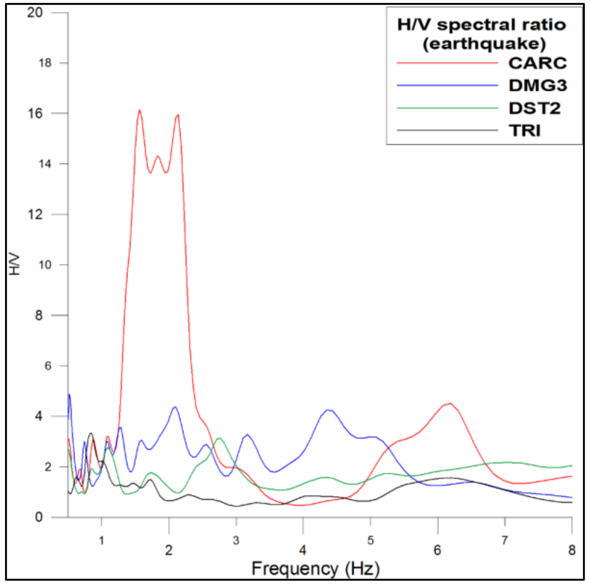
Palazzo Carciotti, Borgo Teresiano, Trieste



Stazione CARC - Borgo Teresiano - Trieste

Palazzo Carciotti, Borgo Teresiano, Trieste





Una corretta valutazione del rischio sismico si basa sul confronto tra tre parametri determinanti:

1. **Pericolosità sismica (P)**: coincide con la sismicità del luogo. Rappresenta la probabilità che terremoti di una certa entità si verifichino in una determinata zona e in un periodo specifico;

2. **Vulnerabilità sismica (V)**: misura la disposizione di una costruzione a subire danni a causa di un sisma e la sua capacità o resistenza ad azioni sismiche;

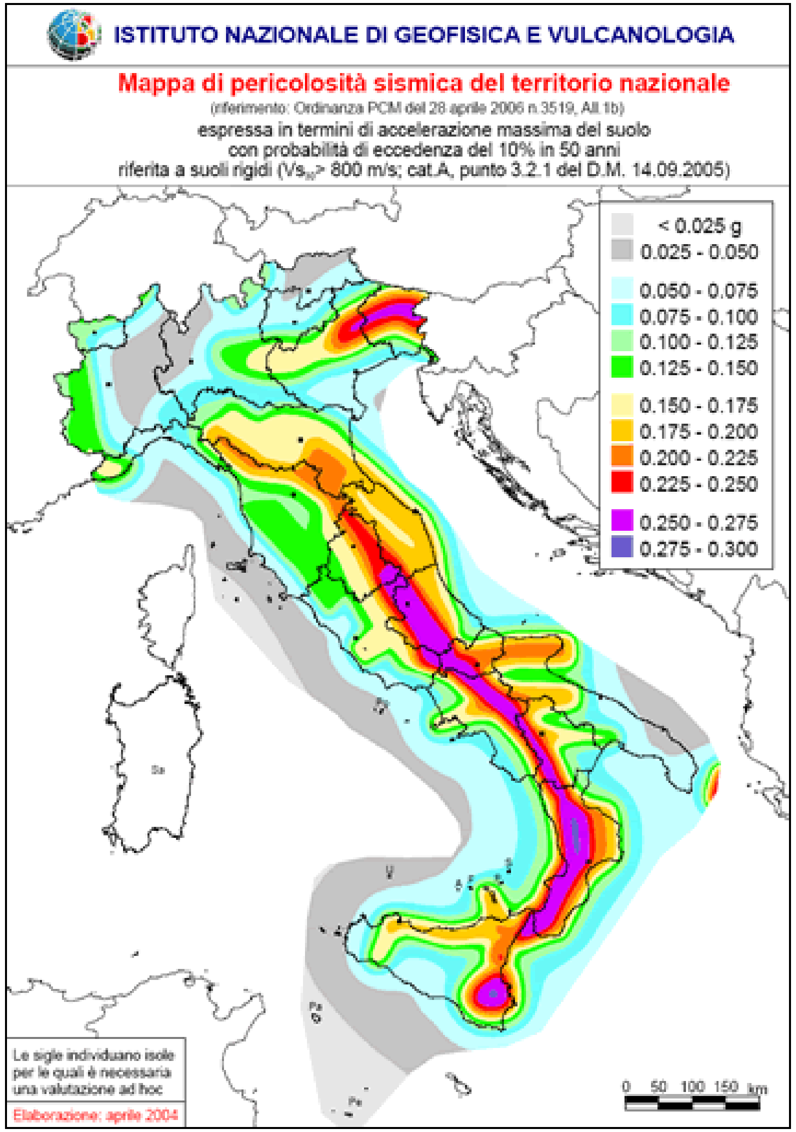
3. **Esposizione (E):** incentrata sulla salvaguardia della vita umana, ipotizza l'insieme di vite umane e di risorse materiali che possono andare perduti per effetto del sisma.

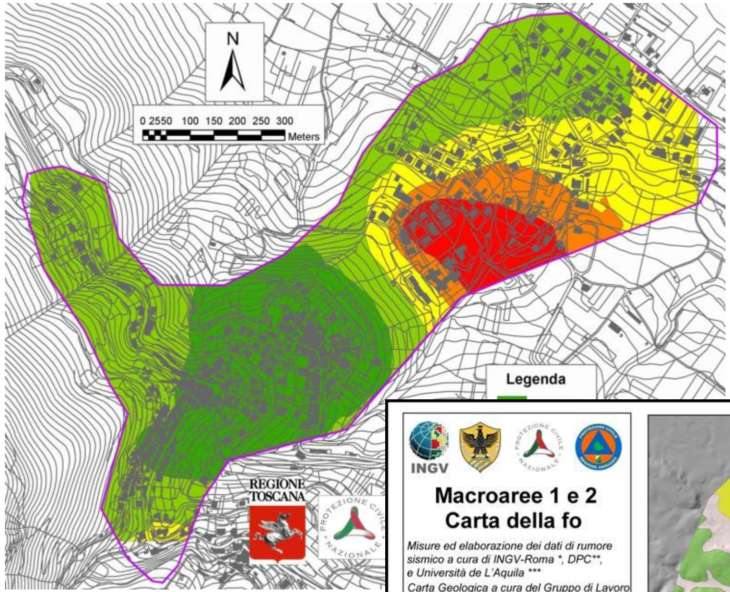
La definizione del rischio sismico è quindi data dalla seguente funzione:

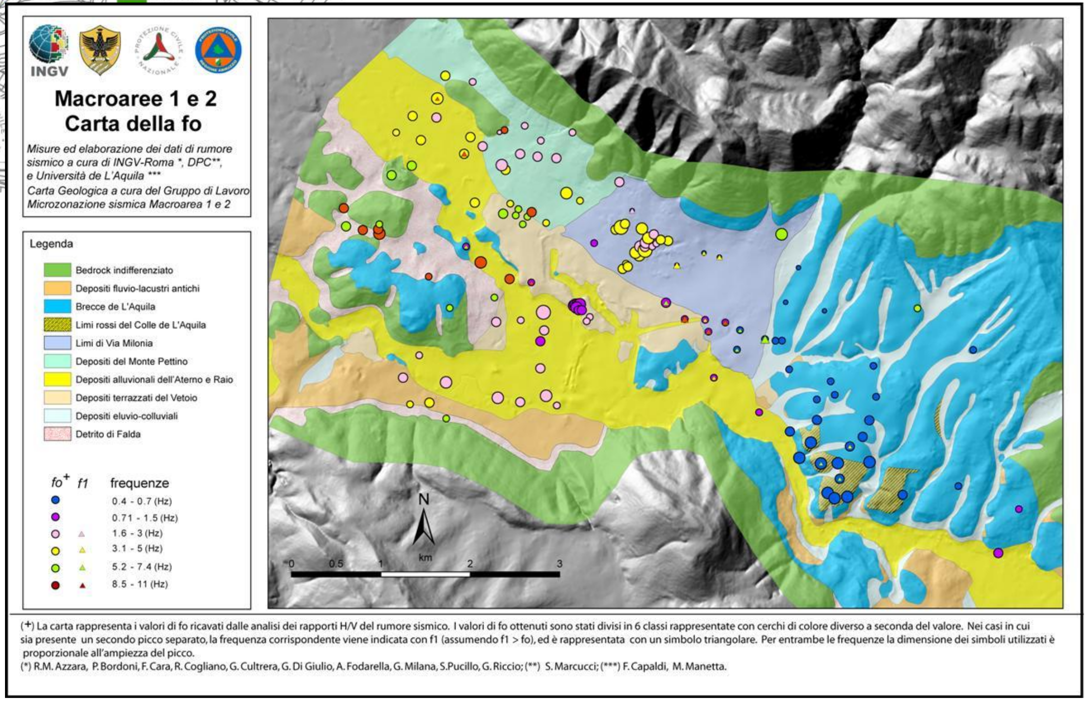
$$\mathbf{R = P \times V \times E}$$

Mappa pericolosità sismica

Microzonazione sismica







Rapporto automatico, in tempo reale per la protezione civile

26/10/2016 21:22:59 ORID: 344475 EVID: 344434

PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

Earthquake AUTOMATIC REPORT

Dipartimento della Protezione Civile - Rome - Italy
Rete Accelerometrica Nazionale
RAN

lo Title]

WARNING:
These information are preliminary
and may be revised when more data are available.

Event: Castelsantangelo_sul_Nera
Origin time: 2016/10/26 19:18:06
Latitude: 42.898 Longitude: 13.121
Magnitude Ml: 6.0
AGENCY: DPC

Seismic Moment: 5.08e+18 Nm
Mw: 6.2
AGENCY: DPC

Records analyzed by procedure: 231
Selected limits: max distance=100. km min PGA= 1.0 cm/s*s
min PGA to show response spectra= 1.0 cm/s*s
Records inside the selected limits: 142 response spectra inside the limits: 142

Nearest station: NRC distance: 11.84 km
HGN - PGA=346.88 cm/s*s, PGV=19.96 cm/s
Max recorded PGA: 606.13 cm/s*s Station: FOC Foligno_Colfiorito
HGE - distance=23.06 km, PGV=19.60 cm/s

Procedure implemented by SeisRaM group. University of Trieste, Italy - ver: SPT - 2015

Event: Castelsa - Origin time: 2016/10/26 19:18:06 Lat:42.898 Lon:13.121 Ml = 6.0 Agency: DPC
Seismic moment: 5.080e+18 Nm - Mw = 6.2 Agency: DPC

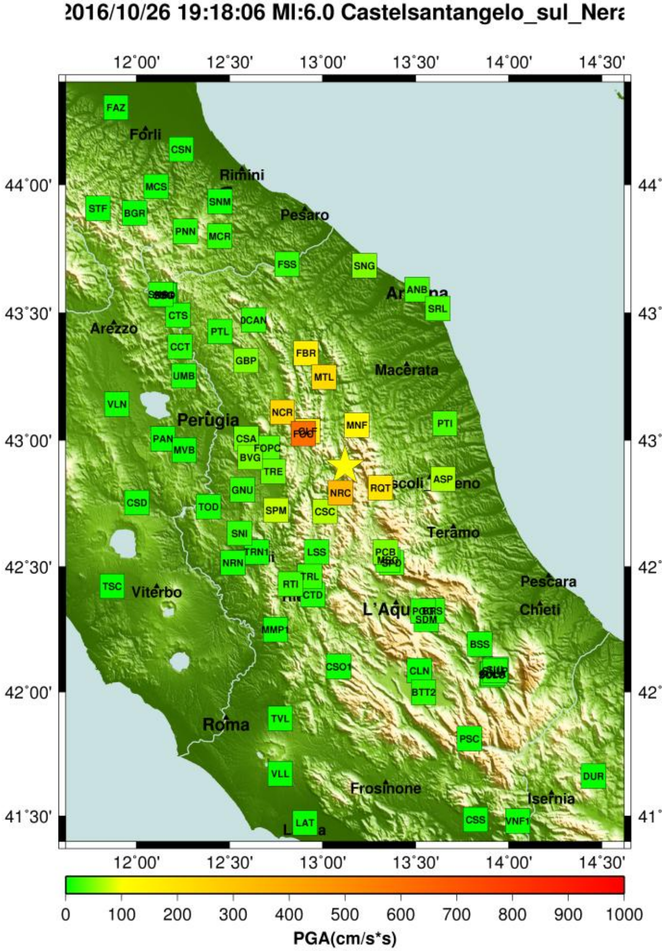
sta	chan	dista km	filter Hz	PGA cm/s*s	EPA cm/s*s	PGV cm/s	PGD cm	PSA03 cm/s*s	PSA10 cm/s*s	PSA30 cm/s*s	EC8	location
NRC	HGE	12	0.2-50.0	242.42	172.05	19.01	2.00	357.42	174.66	16.34	B	Norcia
NRC	HGN	12	0.2-50.0	346.88	269.93	19.96	1.74	398.15	105.84	30.85	B	Norcia
NRC	HGZ	12	0.2-50.0	211.46	134.60	8.75	1.09	275.52	63.99	12.05	B	Norcia
RQT	HGE	18	0.2-50.0	188.81	115.67	5.36	0.77	169.52	49.68	9.30	B*	Arquata_Del_Tronto
RQT	HGN	18	0.2-50.0	147.80	109.77	5.64	1.03	255.30	64.97	14.20	B*	Arquata_Del_Tronto
RQT	HGZ	18	0.2-50.0	116.17	50.55	3.98	0.90	113.45	41.83	14.39	B*	Arquata_Del_Tronto
MNF	HGE	19	0.2-50.0	128.04	81.35	8.36	1.61	178.54	68.11	10.65	A*	MonteFiegni-Fiastra
MNF	HGN	19	0.2-50.0	87.18	81.19	7.64	2.33	195.07	123.40	30.46	A*	MonteFiegni-Fiastra
MNF	HGZ	19	0.2-50.0	98.35	68.07	5.77	2.55	180.01	81.65	26.25	A*	MonteFiegni-Fiastra
CSC	HGE	22	0.2-50.0	70.02	53.03	3.63	0.95	109.97	47.65	13.34	B	Cascia
CSC	HGN	22	0.2-50.0	68.86	40.81	3.25	0.82	93.76	65.26	14.69	B	Cascia
CSC	HGZ	22	0.2-50.0	39.76	31.57	2.56	0.75	64.54	21.66	12.66	B	Cascia
CLF	HGE	22	0.2-50.0	122.01	91.70	11.04	1.85	259.34	237.60	13.97	D	Colfiorito_Casone
CLF	HGN	22	0.2-50.0	155.64	122.26	13.69	2.57	264.80	357.05	18.22	D	Colfiorito_Casone
CLF	HGZ	22	0.2-50.0	82.97	81.19	5.35	1.02	106.22	74.43	7.38	D	Colfiorito_Casone
FOC	HGE	23	0.2-50.0	606.13	477.17	19.60	0.90	1252.98	47.27	7.49	C*	Foligno_Colfiorito
FOC	HGN	23	0.2-50.0	365.33	215.49	9.57	1.10	426.11	56.75	9.40	C*	Foligno_Colfiorito
FOC	HGZ	23	0.2-50.0	169.10	88.95	3.64	0.51	193.81	17.14	6.55	C*	Foligno_Colfiorito
TRE	HGE	31	0.2-50.0	40.25	36.64	2.96	0.86	75.79	39.66	13.70	C*	Trevi
TRE	HGN	31	0.2-50.0	37.69	34.26	2.73	0.50	82.20	36.89	5.80	C*	Trevi
TRE	HGZ	31	0.2-50.0	25.86	20.39	2.13	0.63	53.66	26.59	6.75	C*	Trevi
FOPC	HGE	35	0.2-50.0	32.45	30.05	2.69	0.70	58.73	36.90	10.89	na	Foligno Prot Civ Reg
FOPC	HGN	35	0.2-50.0	31.67	30.28	2.78	0.97	90.06	57.15	11.56	na	Foligno Prot Civ Reg
FOPC	HGZ	35	0.2-50.0	26.51	18.02	1.92	0.49	35.57	29.77	6.73	na	Foligno Prot Civ Reg
SPM	HGE	36	0.2-50.0	75.94	45.17	2.17	0.55	97.51	13.07	5.23	A*	Spoleto_Monteluco
SPM	HGN	36	0.2-50.0	57.39	44.07	1.74	0.69	110.17	11.66	8.12	A*	Spoleto_Monteluco
SPM	HGZ	36	0.2-50.0	23.11	15.26	1.10	0.40	28.21	9.76	6.77	A*	Spoleto_Monteluco
NCR	HGE	36	0.2-50.0	225.76	182.83	7.67	0.64	239.86	42.60	5.65	E	Nocera_Umbra

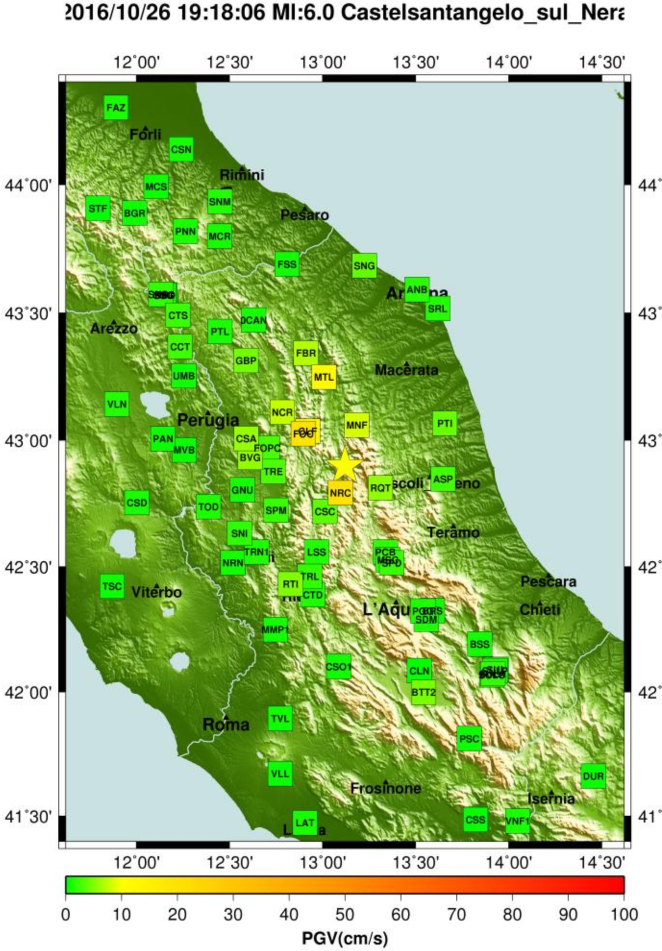
dista = epicentral distance
filter = automatic band pass butterworth filter
EC8 = site classification (Eurocode from ITACA)
PGA,PGV,PGD = peak ground acceleration, velocity and displacement
EPA = effective ground acceleration (Kramer, 1996)
PSA03,PSA10,PSA30 = spectral acceleration (0.3, 1.0, 3.0 sec)

SeisRaM

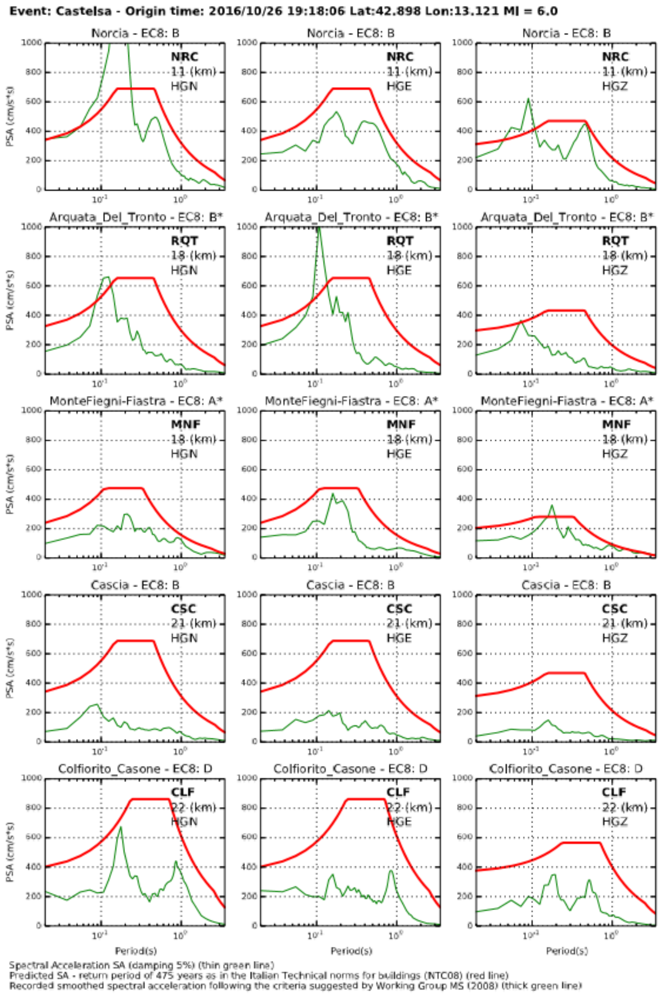
PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

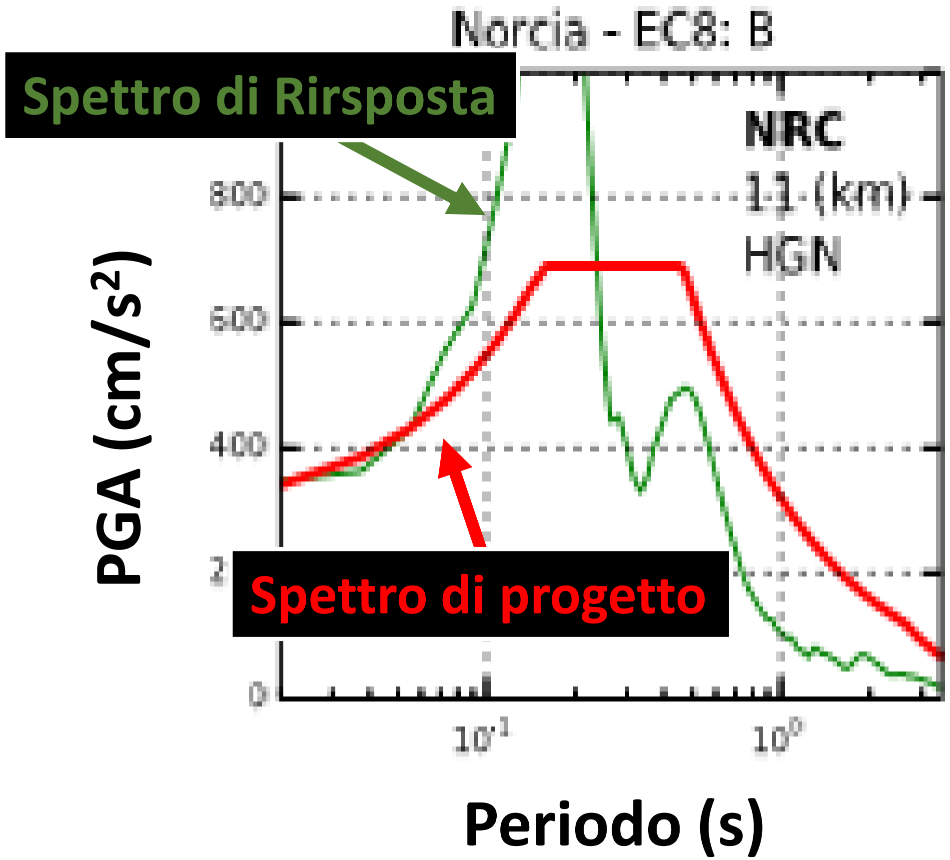
Analisi automatica, in tempo reale, dei dati accelerometrici per la protezione civile



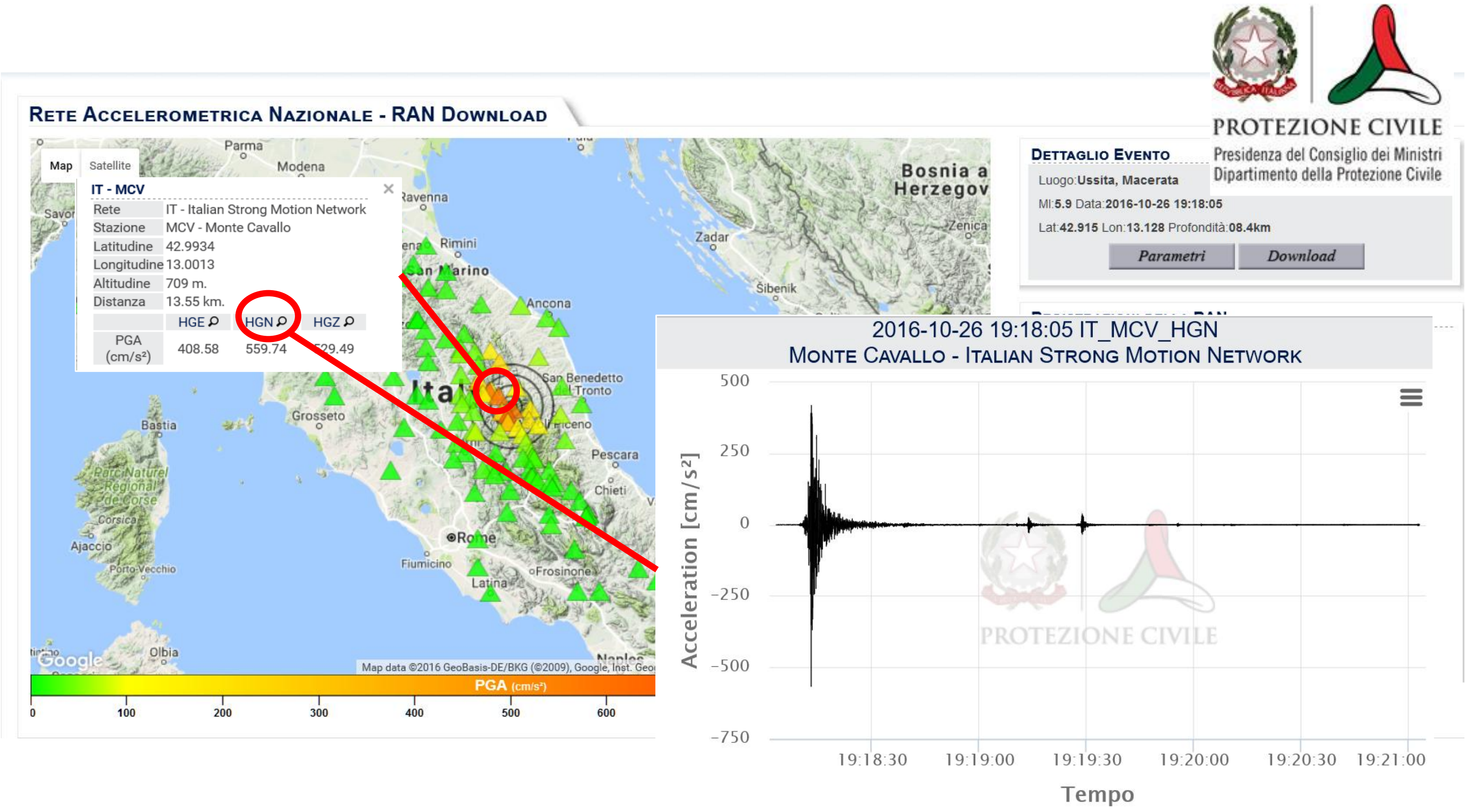


Rapporto automatico, in tempo reale per la protezione civile





http://ran.protezionecivile.it



http://ran.protezionecivile.it

PARAMETRI RAN

Elenco parametri RAN	Epicentro (auth: INGV) Ml 5.9, 2016-10-26 19:18:05 (UTC) - Ussita, Macerata														
Sta	**Can**	**Lat (°)**	**Lon (°)**	**Nome Stazione**	**Filtro Hz**	**dist km**	**PGA cm/s²**	**PGV cm/s**	**PSA03 cm/s²**	**PSA10 cm/s²**	**PSA30 cm/s²**	**Arias cm/s**	**Housner cm**	**EC8**	
CNE	HGE	42.8944	13.1528	Castel Santangelo sul Nera	Ba 0.2 6 50.0 6	3.11	553.544495	23.362356	1288.220337	232.333084	18.377827	107.167976	94.148964	-	
CNE	HGN	42.8944	13.1528	Castel Santangelo sul Nera	Ba 0.2 6 50.0 6	3.11	420.069122	30.533468	865.694702	373.006439	30.073645	93.419106	116.965912	-	
CNE	HGZ	42.8944	13.1528	Castel Santangelo sul Nera	Ba 0.2 6 50.0 6	3.11	489.291260	15.159959	531.467957	116.675125	31.444519	93.735588	51.707516	-	
CMI	HGE	42.8504	13.0928	Campi	Ba 0.2 6 50.0 6	7.62	685.462830	48.729881	1781.117920	508.715515	40.544647	208.076309	174.904205	-	
CMI	HGN	42.8504	13.0928	Campi	Ba 0.2 6 50.0 6	7.62	349.890320	23.547428	799.176025	225.277084	31.580013	91.011108	78.134651	-	
CMI	HGZ	42.8504	13.0928	Campi	Ba 0.2 6 50.0 6	7.62	495.512177	11.858644	335.602478	113.827332	15.718957	56.689289	41.996677	-	
PRE	HGE	42.8793	13.0334	Preci	Ba 0.2 6 50.0 6	8.80	282.131958	7.655034	343.694275	61.494850	14.080216	29.066908	30.227024	-	
PRE	HGN	42.8793	13.0334	Preci	Ba 0.2 6 50.0 6	8.80	239.329285	9.614402	365.353668	49.514091	21.829815	34.803505	27.257990	-	
PRE	HGZ	42.8793	13.0334	Preci	Ba 0.2 6 50.0 6	8.80	174.519302	5.216872	188.199326	51.470867	12.814964	16.671478	27.194874	-	
MCV	HGE	42.9934	13.0013	Monte Cavallo	Ba 0.2 6 50.0 6	13.55	408.582764	11.220574	390.395691	74.556282	13.457872	80.424057	35.383453	-	
MCV	HGN	42.9934	13.0013	Monte Cavallo	Ba 0.2 6 50.0 6	13.55	559.737732	14.318295	954.867126	62.464130	19.381353	111.353828	47.699158	-	
MCV	HGZ	42.9934	13.0013	Monte Cavallo	Ba 0.2 6 50.0 6	13.55	529.489319	7.429808	192.979385	61.325577	8.175445	66.780632	22.970127	-	
NOR	HGE	42.7924	13.0924	Norcia	Ba 0.2 6 50.0 6	13.91	222.447205	16.471518	425.226410	248.260025	13.641493	25.092558	66.180450	C*	
NOR	HGN	42.7924	13.0924	Norcia	Ba 0.2 6 50.0 6	13.91	137.548615	9.917775	235.951157	154.517929	40.185349	16.744089	51.758324	C*	
NOR	HGZ	42.7924	13.0924	Norcia	Ba 0.2 6 50.0 6	13.91	96.897064	7.086030	147.115463	105.094620	12.112900	10.870301	34.973919	C*	
NRC	HGE	42.7925	13.0964	Norcia	Ba 0.2 6 50.0 6	13.91	242.267395	18.992956	357.196442	174.554520	16.333855	27.599295	60.018810	B	
NRC	HGN	42.7925	13.0964	Norcia	Ba 0.2 6 50.0 6	13.91	346.669495	19.946661	397.902496	105.774551	30.831427	49.789341	63.566521	B	
NRC	HGZ	42.7925	13.0964	Norcia	Ba 0.2 6 50.0 6	13.91	211.332703	8.743941	275.348328	63.945946	12.041706	17.117792	32.929207	B	
MMO	HGE	42.8993	13.3268	Montemonaco	Ba 0.2 6 50.0 6	16.45	171.050262	6.342821	302.757111	79.596825	11.418564	18.580093	31.965408	-	
MMO	HGN	42.8993	13.3268	Montemonaco	Ba 0.2 6 50.0 6	16.45	170.994492	11.574311	306.006470	168.568008	18.389462	24.084583	50.906113	-	
MMO	HGZ	42.8993	13.3268	Montemonaco	Ba 0.2 6 50.0 6	16.45	93.511299	4.930449	161.708450	66.573303	9.277277	9.444488	20.906601	-	
MNF	HGE	43.0596	13.1844	MonteFiegni-Fiastra	Ba 0.2 6 50.0 6	16.75	127.960503	8.353045	178.423233	68.049622	10.685244	7.762556	26.479792	A*	
MNF	HGN	43.0596	13.1844	MonteFiegni-Fiastra	Ba 0.2 6 50.0 6	16.75	87.120094	7.634027	194.951843	123.312218	30.512157	7.788480	31.249706	A*	
MNF	HGZ	43.0596	13.1844	MonteFiegni-Fiastra	Ba 0.2 6 50.0 6	16.75	98.285515	5.765221	179.898712	81.600746	26.230217	5.701234	27.065187	A*	
RQT	HGE	42.8130	13.3110	Arquata_Del_Tronto	Ba 0.2 6 50.0 6	18.66	188.689743	5.358561	169.419571	49.650517	9.295050	42.272381	23.045345	B*	
RQT	HGN	42.8130	13.3110	Arquata_Del_Tronto	Ba 0.2 6 50.0 6	18.66	147.712723	5.635134	255.138031	64.930031	14.191557	29.742075	23.973879	B*	
RQT	HGZ	42.8130	13.3110	Arquata_Del_Tronto	Ba 0.2 6 50.0 6	18.66	116.099098	3.978818	113.381508	41.808716	14.379747	8.726532	16.634663	B*	
FCC	HGE	42.7545	13.1932	Forca Canapine	Ba 0.2 6 50.0 6	18.91	135.504105	4.119731	209.573334	30.651966	10.311465	11.038939	17.468452	-	
FCC	HGN	42.7545	13.1932	Forca Canapine	Ba 0.2 6 50.0 6	18.91	113.644394	4.952429	142.733704	44.352097	8.955695	10.854320	17.821522	-	
FCC	HGZ	42.7545	13.1932	Forca Canapine	Ba 0.2 6 50.0 6	18.91	61.479443	2.988155	111.270401	27.469952	14.562296	3.628394	12.334505	-	
CLF	HGE	43.0367	12.9204	Colfiorito_Casone	Ba 0.2 6 50.0 6	21.66	121.932213	11.027856	259.174255	237.457764	13.959499	19.793224	49.492130	D	
CLF	HGN	43.0367	12.9204	Colfiorito_Casone	Ba 0.2 6 50.0 6	21.66	155.547745	13.685712	264.637268	356.833374	18.193239	29.179775	75.505699	D	

PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

o
ata
6 19:18:05
Profondità:08.4km
ametri
Download

LLA RAN

:3.4 Prof:08.2km Nrecs:43
:3.3 Prof:10.7km Nrecs:35
:3.1 Prof:07.1km Nrecs:29
:3.5 Prof:07.7km Nrecs:36
:3.3 Prof:08.7km Nrecs:35
:3.0 Prof:08.3km Nrecs:29
:3.3 Prof:09.6km Nrecs:40
:3.1 Prof:08.6km Nrecs:36
:2.8 Prof:10.2km Nrecs:21
:3.1 Prof:10.7km Nrecs:26
:2.8 Prof:10.5km Nrecs:16
:3.1 Prof:09.1km Nrecs:30
:3.4 Prof:08.8km Nrecs:38
:4.0 Prof:08.4km Nrecs:26
:4.2 Prof:08.6km Nrecs:59

Mappe di scuotimento in tempo reale

Registrazione sismica – correzione strumentale

Estrazione parametri del moto del terreno (PGA, PGV, PSA…)

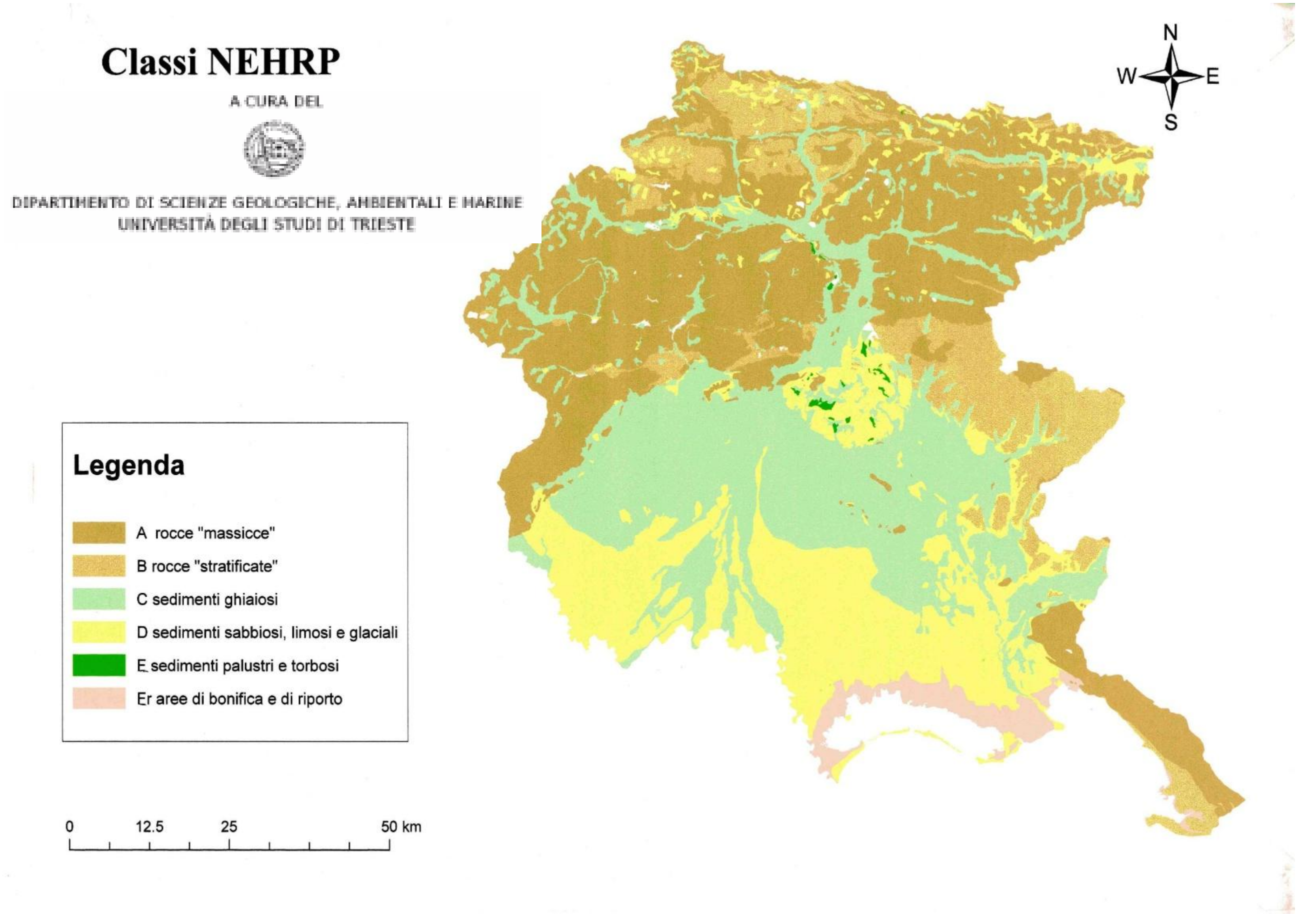
Correzione forme d'onda per effetti di sito (valori su roccia)

Definizione parametri del moto del terreno su griglia da valori sperimentali dove disponibili a breve distanza

Calcolo parametri del moto del terreno su griglia da relazioni di attenuazione "calibrati" per le stazioni "fantasma"

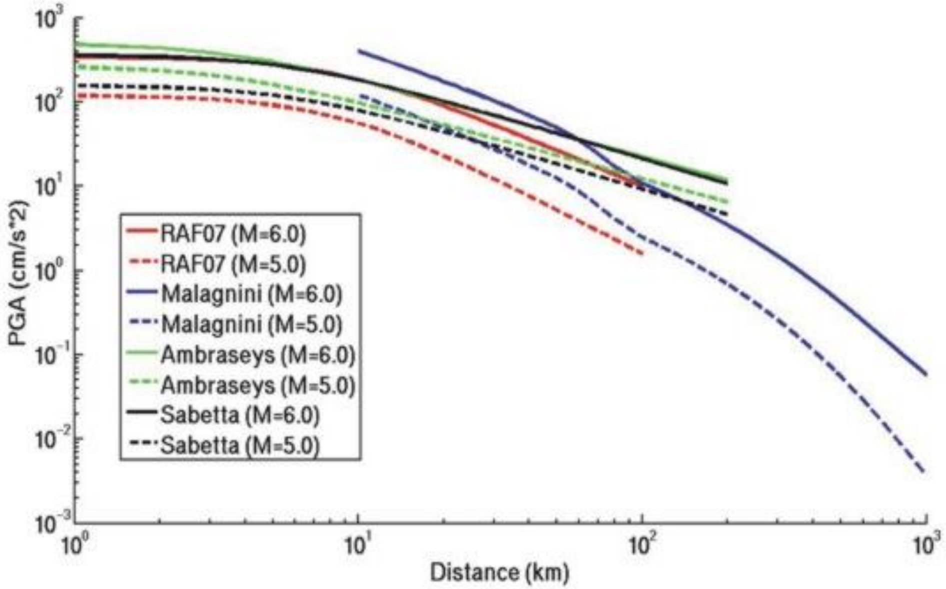
Introduzione degli effetti di sito sui nodi di griglia

Mappe di scuotimento

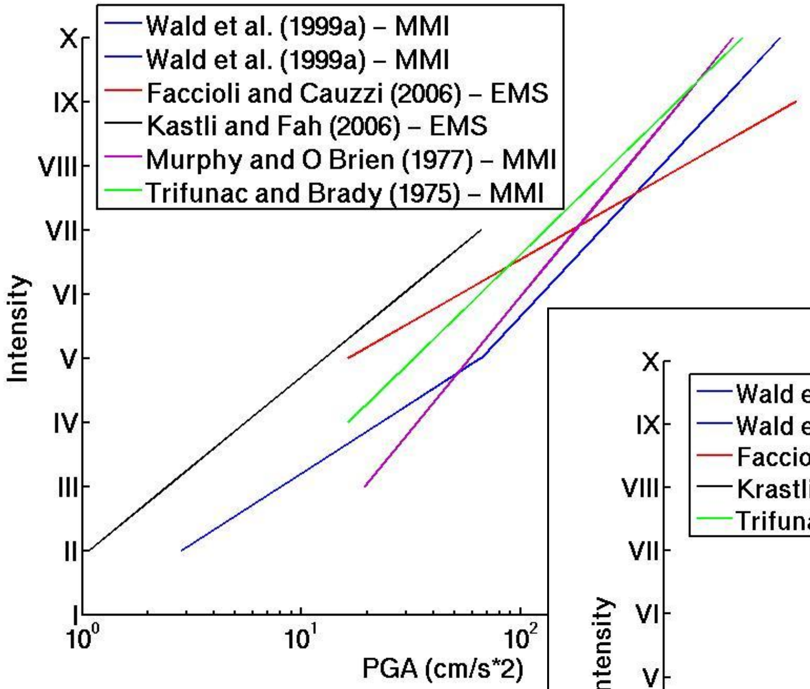


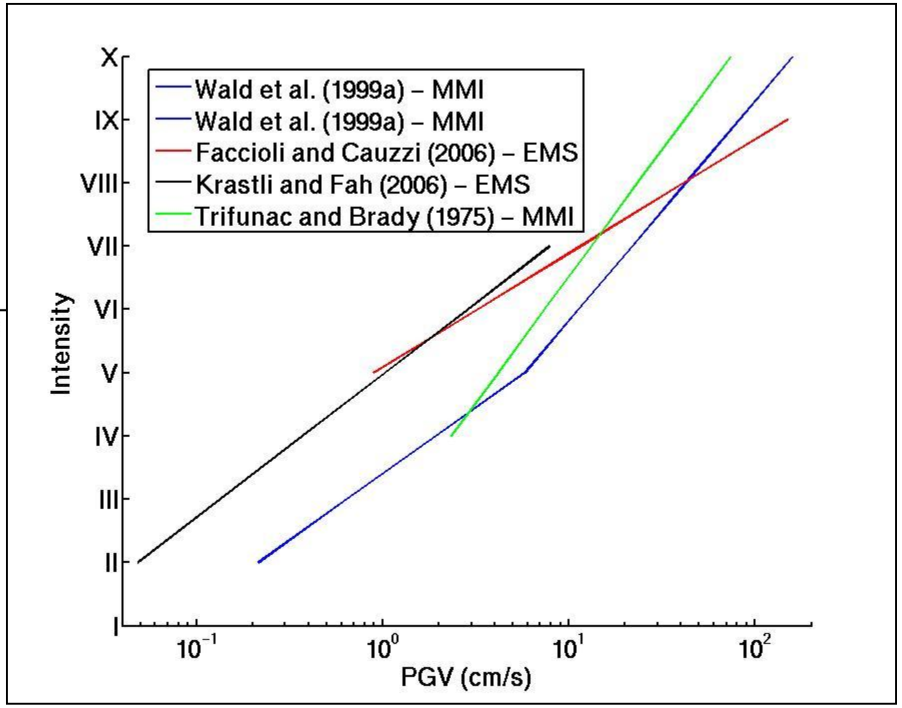
Classi NEHRP
A CURA DEL
DIPARTIMENTO DI SCIENZE GEOLOGICHE, AMBIENTALI E MARINE
UNIVERSITÀ DEGLI STUDI DI TRIESTE
N
W
E
S
Legenda
A rocce "massicce"
B rocce "stratificate"
C sedimenti ghiaiosi
D sedimenti sabbiosi, limosi e glaciali
E sedimenti palustri e torbosi
Er aree di bonifica e di riporto
0
12.5
25
50 km

Relazioni di attenuazione

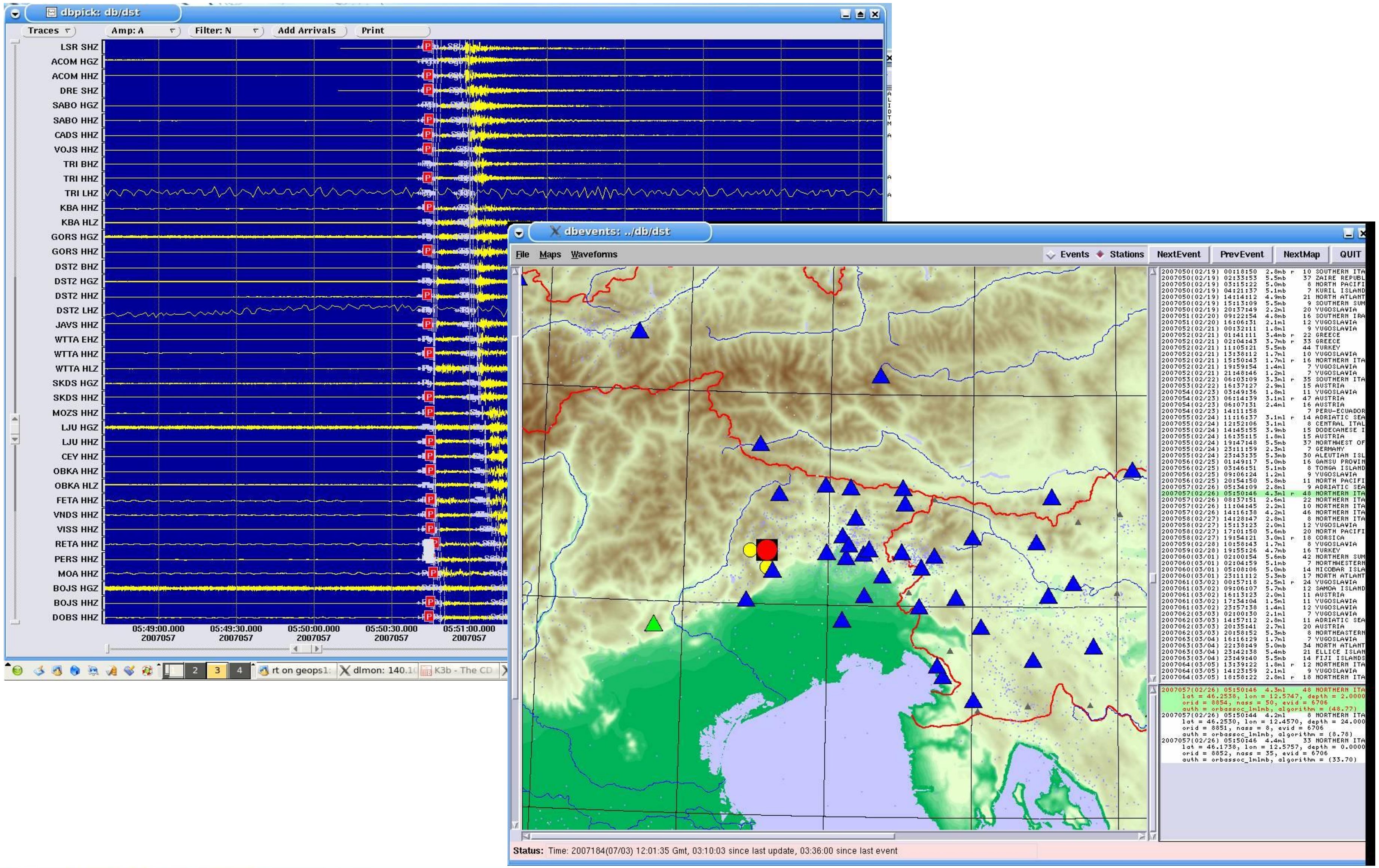


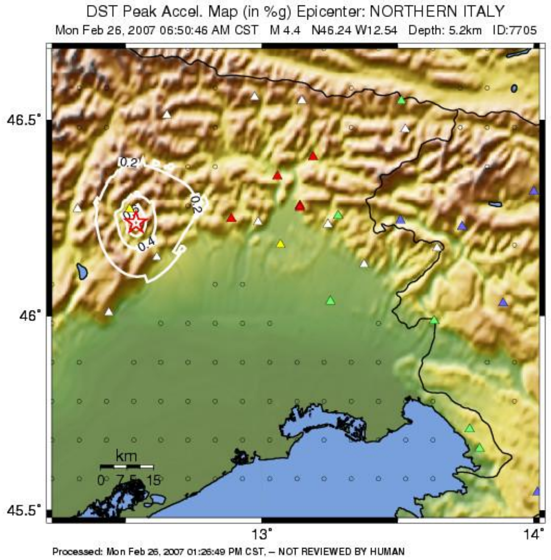
Relazioni PGA/PGV – Intensità

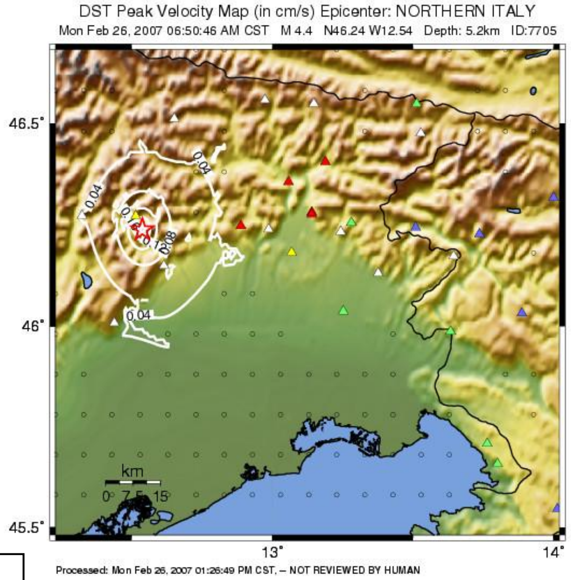


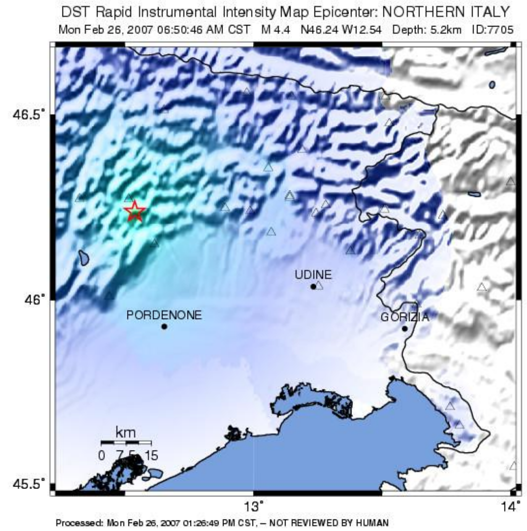


Integrated networks in Southern Alps area

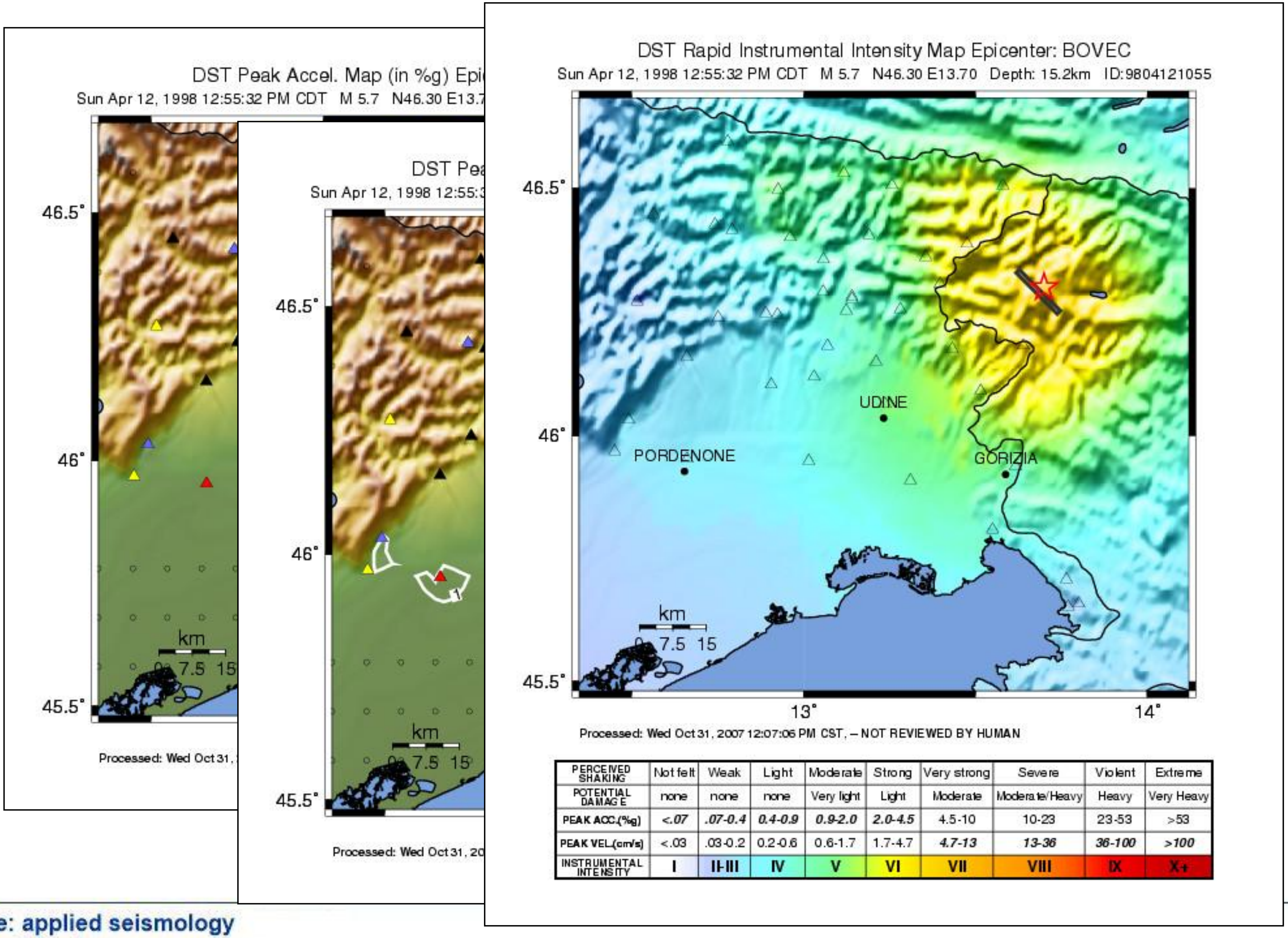






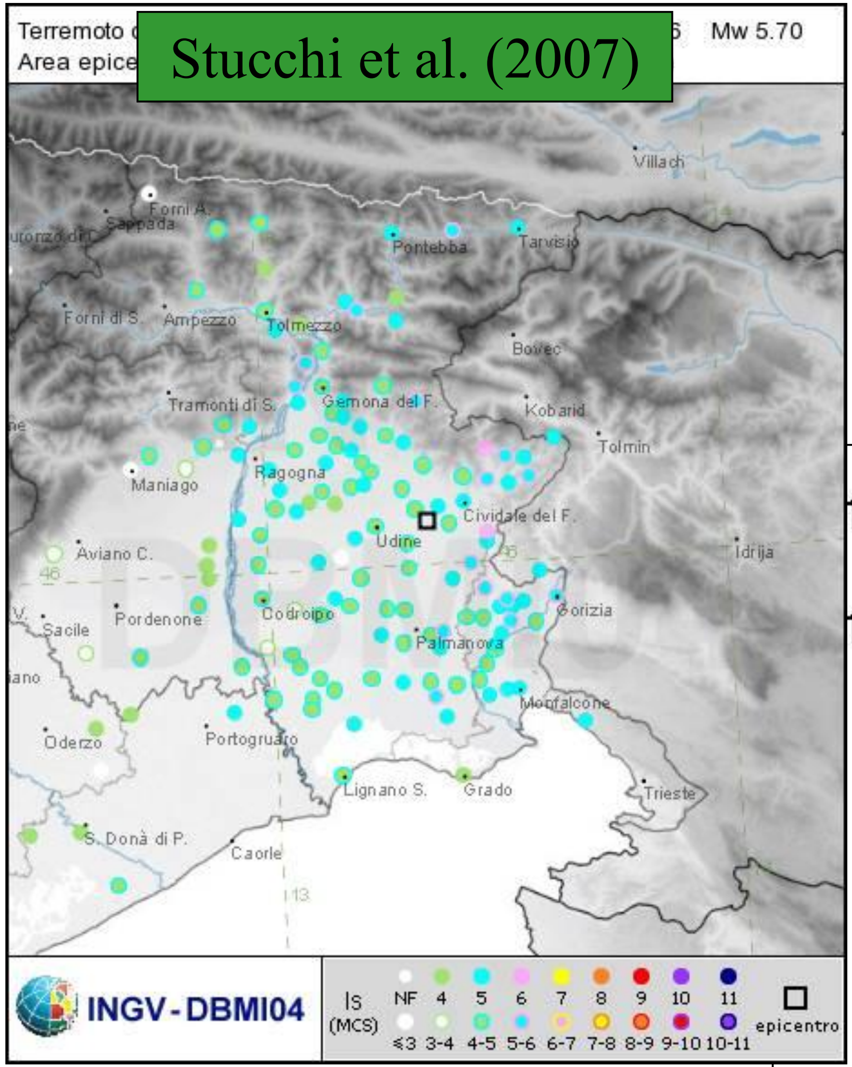


PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.02	.02-.28	.28-.92	.92-3.0	3.0-9.7	9.7-31	31-101	101-329	>124
PEAK VEL.(cm/s)	<.01	.01-.13	.13-.47	.47-1.6	1.6-6.0	6.0-21	21-78	78-281	>281
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+



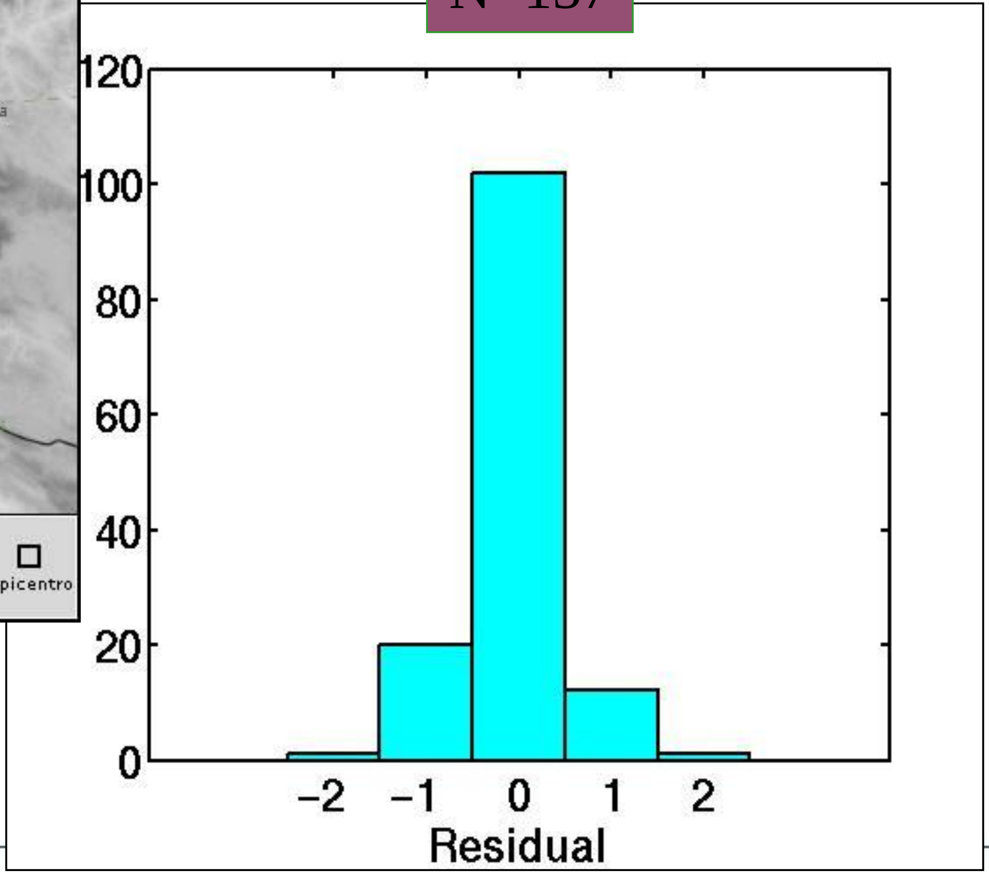
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.07	.07-0.4	0.4-0.9	0.9-2.0	2.0-4.5	4.5-10	10-23	23-53	>53
PEAK VEL.(cm/s)	<.03	.03-0.2	0.2-0.6	0.6-1.7	1.7-4.7	4.7-13	13-36	36-100	>100
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Stucchi et al. (2007)

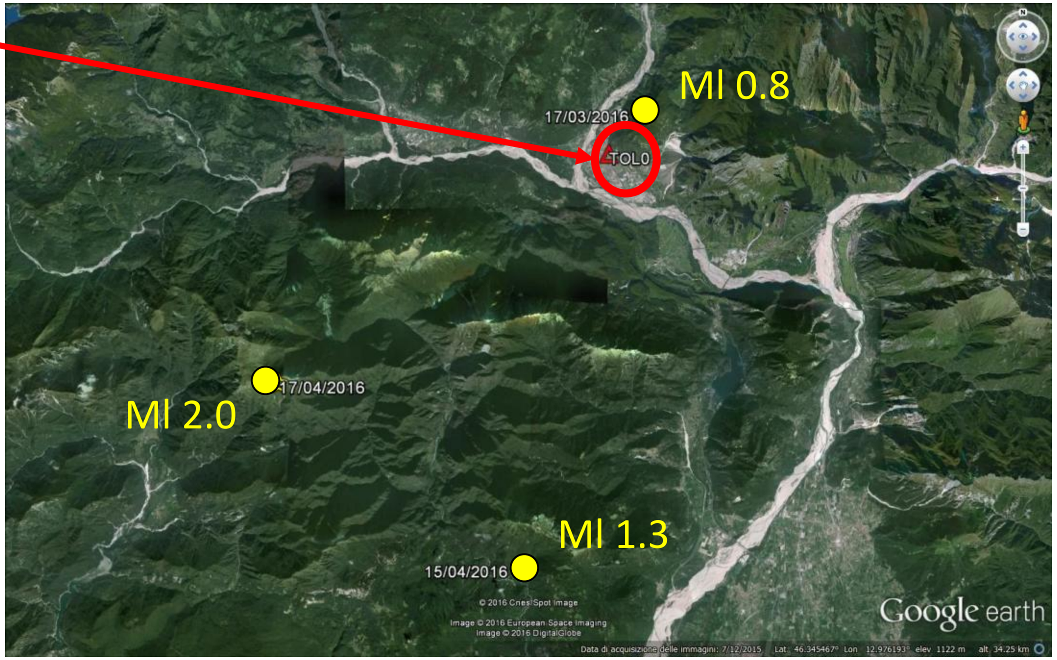


$$Misfit = \frac{\sum_{i=1}^{N} \left| I_{COM} - I_{OBS} \right|}{N} = 0.264$$

N=137

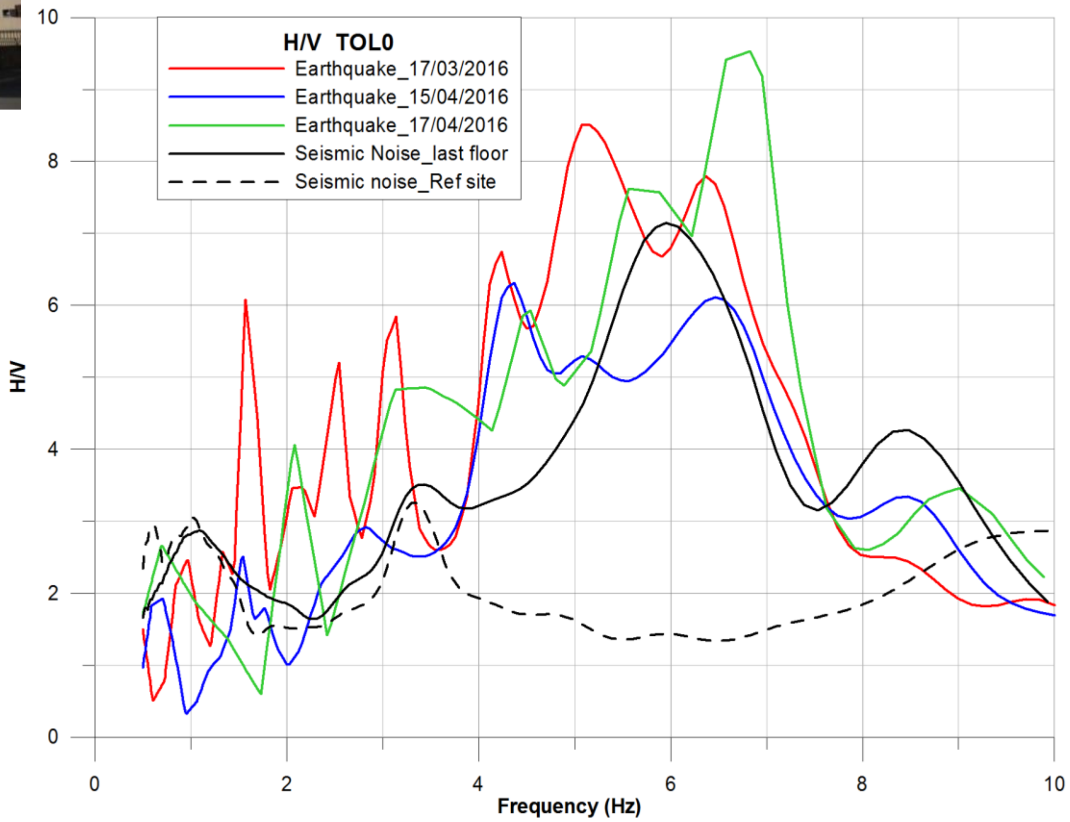


Tolmezzo



Ml 0.8
17/03/2016
TOLO
17/04/2016
Ml 2.0
Ml 1.3
15/04/2016
© 2016 Cnes/Spot Image
Image © 2016 European Space Imaging
Image © 2016 DigitalGlobe
Google earth

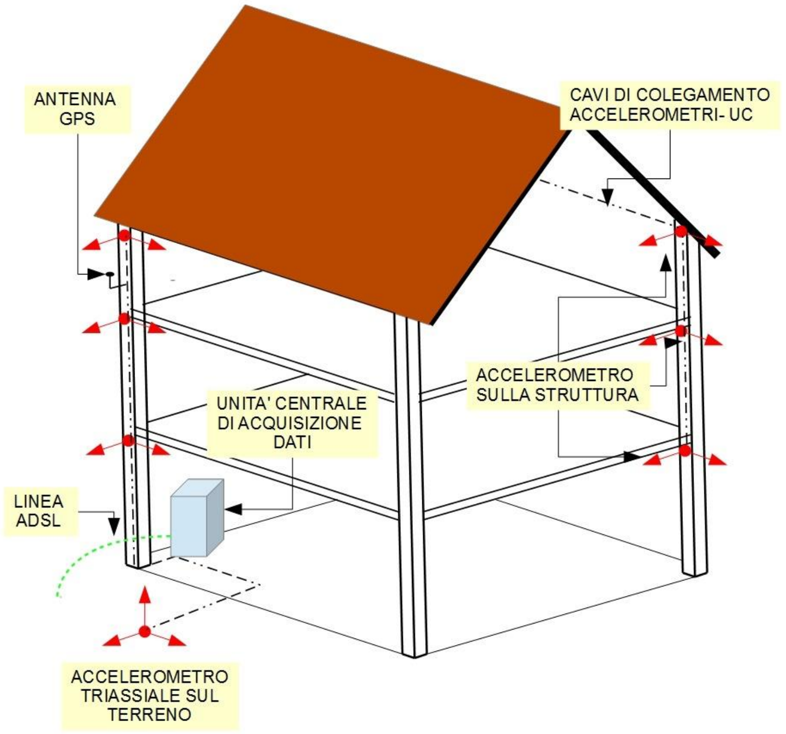
Tolmezzo



H/V TOL0
Earthquake_17/03/2016
Earthquake_15/04/2016
Earthquake_17/04/2016
Seismic Noise_last floor
Seismic noise_Ref site
H/V
Frequency (Hz)
0
2
4
6
8
10

OSSERVATORIO SISMICO DELLE STRUTTURE

"complete" monitoring system



A system for "complete" seismic monitoring of a building consists of a triaxial accelerometer on the ground to an N accelerometers attached to the structure at the level of the various decks.

A sufficient number of accelerometer components are measured for each deck to completely reconstruct its motion
All accelerometers are connected by cable to a central unit that provides synchronized acquisition of signals and writes them to a fixed memory (in case of exceeding certain acceleration thresholds: seismic event)

Data are always referenced with absolute UTC time obtained through a GPS antenna.

By means of an ADSL or UMTS connection, the data are immediately transmitted to a server that processes them and enters them into the data base

Modi elementari o modi naturali di vibrare