Multidisciplinary Workshop at LSM

Oct 18 – 19, 2023

Underground Geophysics at the *INFN - Laboratori Nazionali del Gran Sasso* (*LNGS*)

Gaetano De Luca

(INGV – Osservatorio Nazionale Terremoti)

ISTITUTO NAZIONALE
DI GEOFISICA E VULCANOLOGIA

INFN Istituto Nazionale di Fisica Nucleare


Laboratori Nazionali del Gran Sasso - INFN


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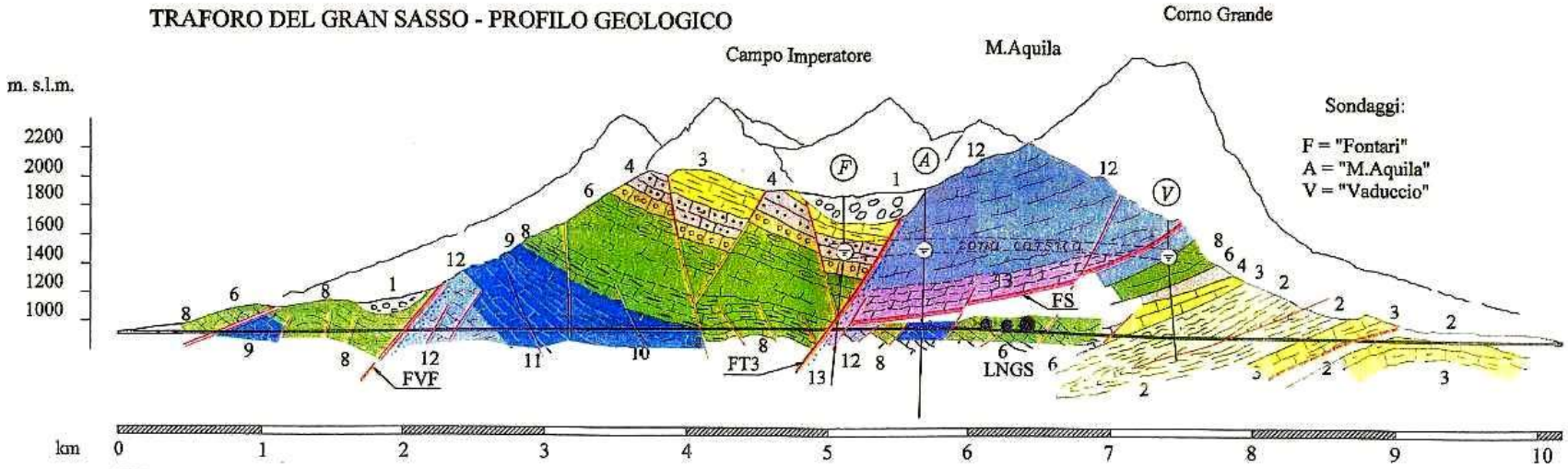
TRAFORO DEL GRAN SASSO - PROFILO GEOLOGICO



blocchi	BLOCCO MERIDIONALE			BLOCCO SETTENTRIONALE		
settori	M1	M2	M3	S1	S2	S3
strutture	Strutture monoclinaliche			Strati in serie rovesciata	Strati in serie normale	

1 Depositi fluvio-glaciali - Quaternario

2 Marne arenacee "Flysch della Laga" - Miocene sup.

3 Calcari marnosi - Miocene medio

4 Calcari glauconitici - Miocene inf.

5 Calcari a macroforaminiferi - Oligocene

6 Calcari selciferi "Scaglia" - Cretaceo sup.

7 Calcari bioclastici massicci - Cretaceo sup.

8 Calcari selciferi a Radiolari - Cretaceo inf.

9 Calcari bioclastici massicci - Giurassico (Dogger-Malm)

10 Marne "Verde Ammonitico"-Giurassico (Lias sup.)

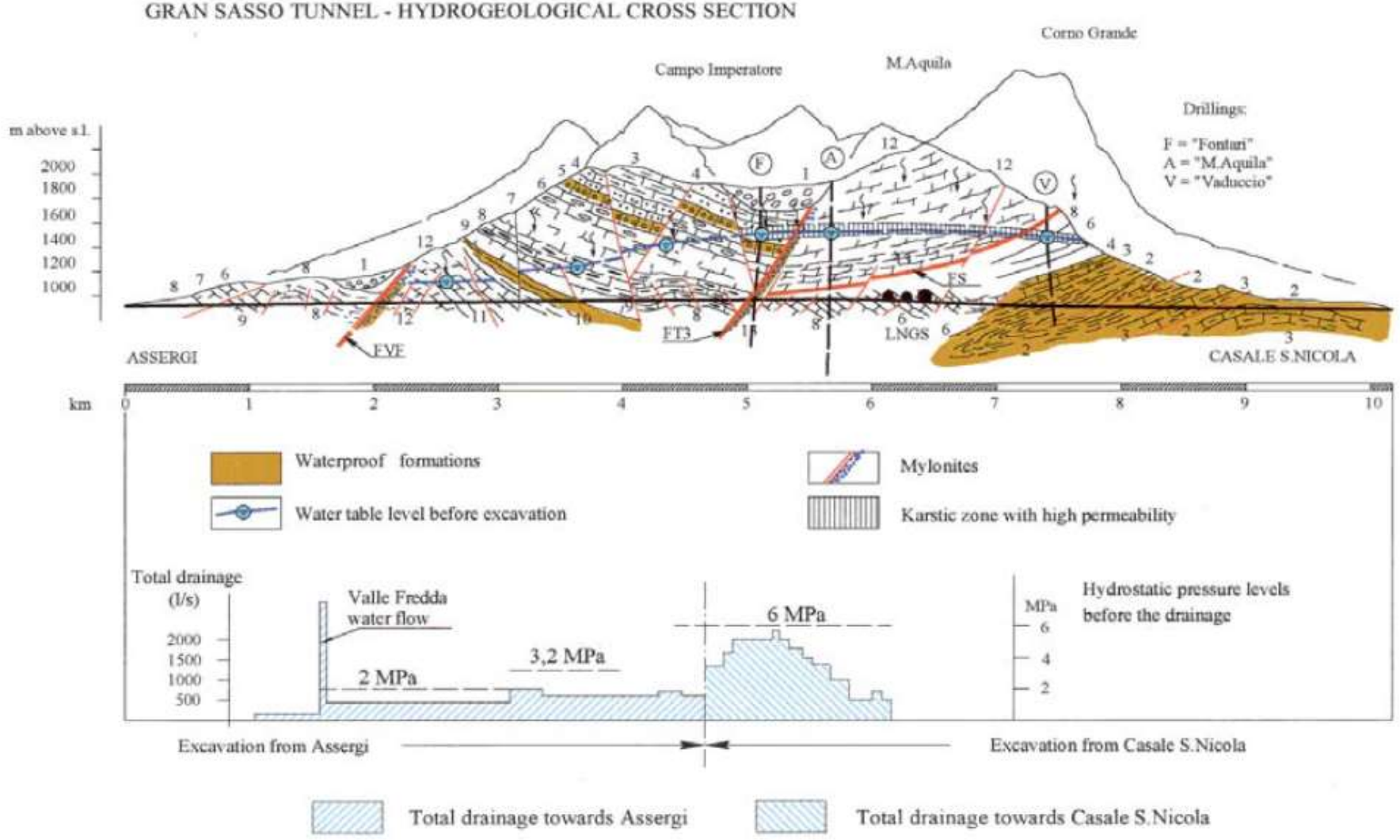
11 Calcari selciferi "Corniola"-Giurassico (Lias medio)

12 Calcari dolomitici "Calcare Massiccio" Giurassico (Lias inf.)

13 Dolomie - Trias sup.

Faglie con milonite

Faglie principali: FVF=faglia di "Valle Fredda" , FT3=faglia "Trasversale3" , FS=Faglia di sovrascorrimento


GRAN SASSO TUNNEL - HYDROGEOLOGICAL CROSS SECTION
Corno Grande
Campo Imperatore
M.Aquila
Drillings:
F = "Fonturi"
A = "M.Aquila"
V = "Vaduccio"
m above s.l.
2000
1800
1600
1400
1200
1000
ASSERGI
EVE
FT3
LNGS
FS
CASALE S.NICOLA
km
0
1
2
3
4
5
6
7
8
9
10
Waterproof formations
Water table level before excavation
Mylonites
Karstic zone with high permeability
Total drainage
(l/s)
2000
1500
1000
500
Valle Fredda
water flow
2 MPa
3,2 MPa
6 MPa
MPa
6
4
2
Hydrostatic pressure levels
before the drainage
Excavation from Assergi
Excavation from Casale S.Nicola
Total drainage towards Assergi
Total drainage towards Casale S.Nicola

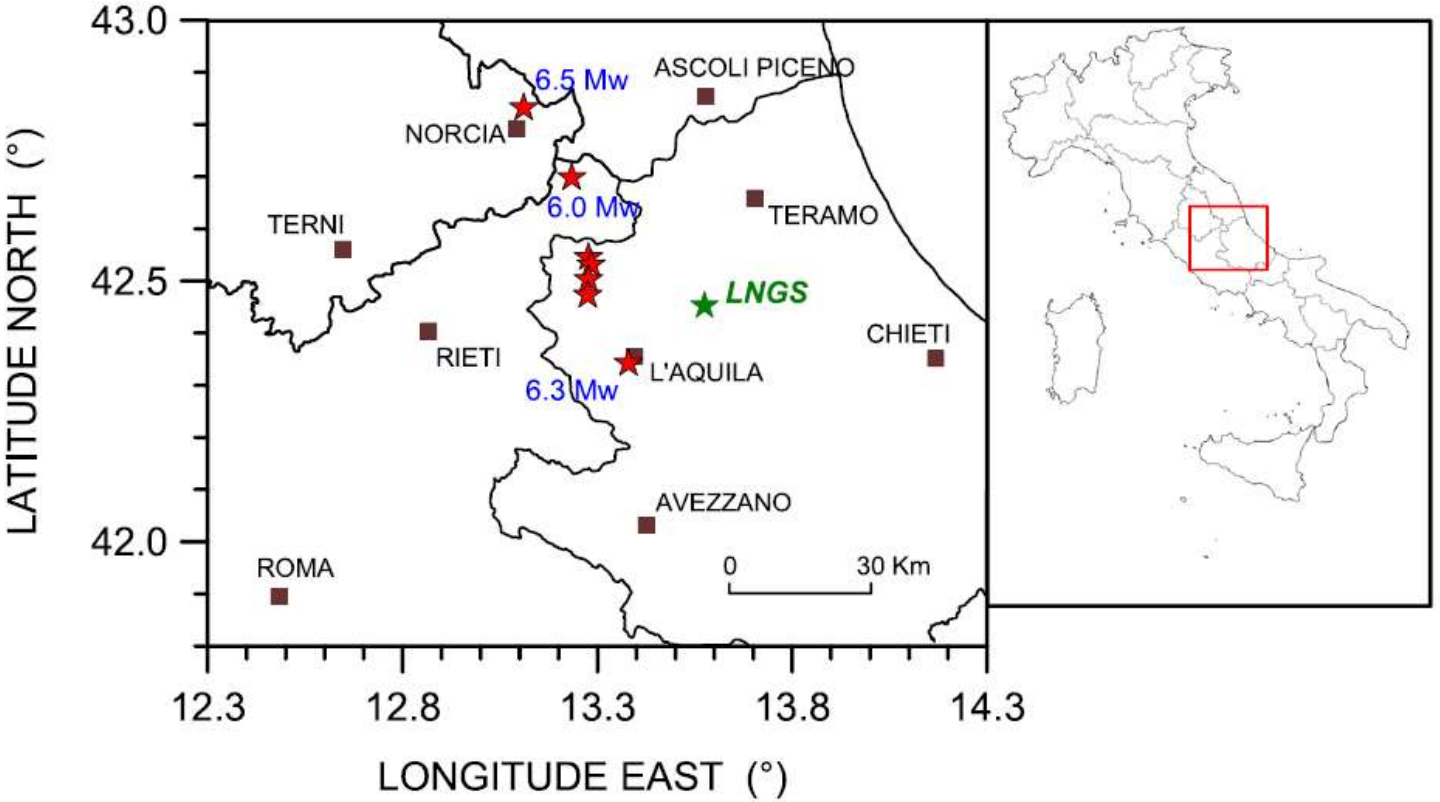


Figure 1. Main earthquakes location map, from Iside data-base[53], of August 2016–January 2017 period (http://cnt.rm.ingv.it/iside); brown squares represent principal towns in the area, black lines for regional boundaries, green star for *LNGS* (Laboratori Nazionali del Gran Sasso) of *INFN* (Istituto Nazionale di Fisica Nucleare) close to the S13 horizontal borehole (distance about 200 m); from northern: red stars for 6.5 M_w of 30 October 2016, 6.0 M_w of 24 August 2016, 5.1 M_w of 18 January 2017 (09:25:40 UT), 5.5 M_w of 18 January 2017 (10:14:10 UT), 5.4 M_w of 18 January 2017 (10:25:24 UT) and 5.0 M_w of 18 January 2017 (13:33:37 UT). We also show the L'Aquila earthquake of 6 April 2009 (6.3 M_w – 01:32:40 UT).

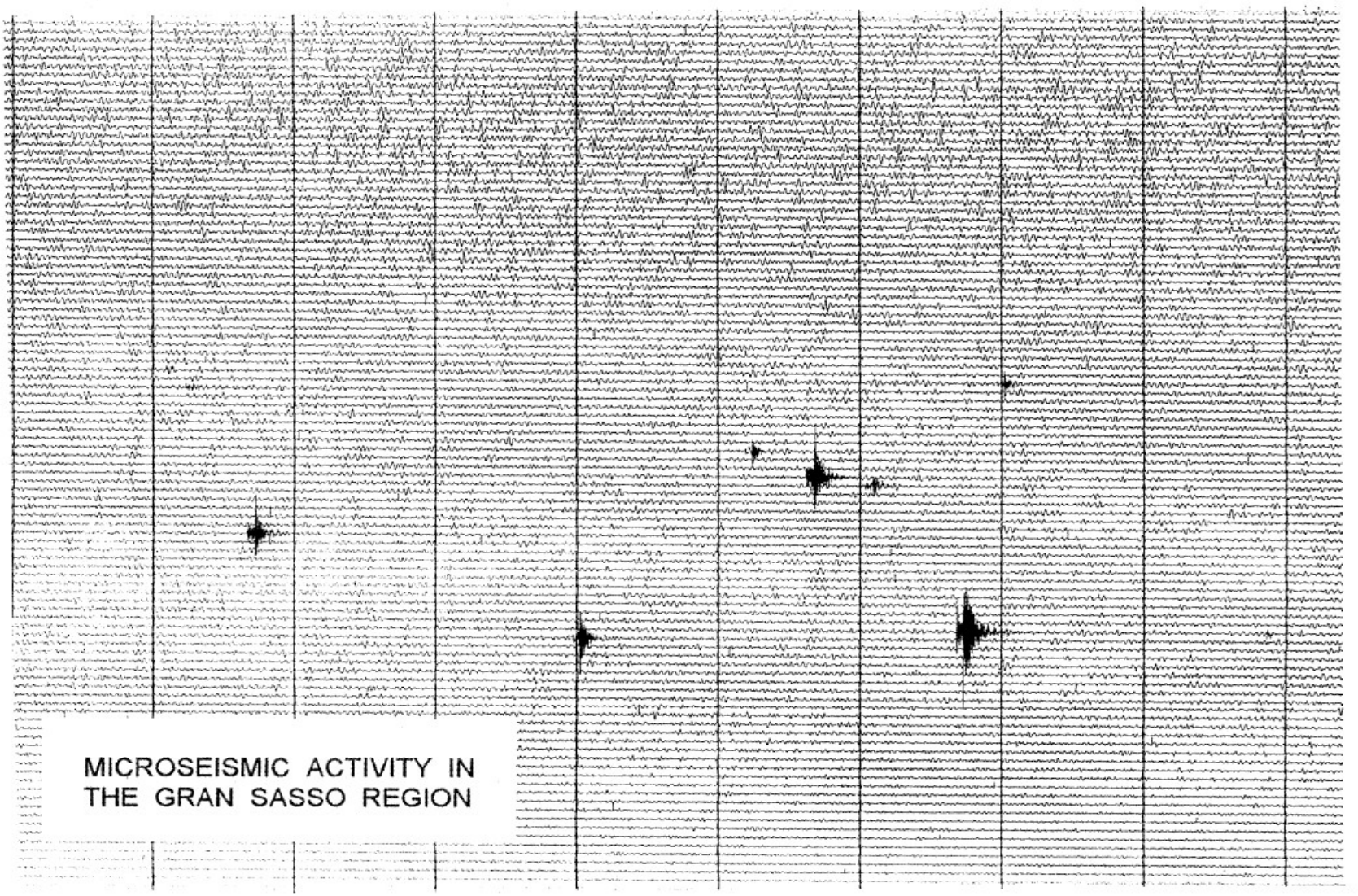
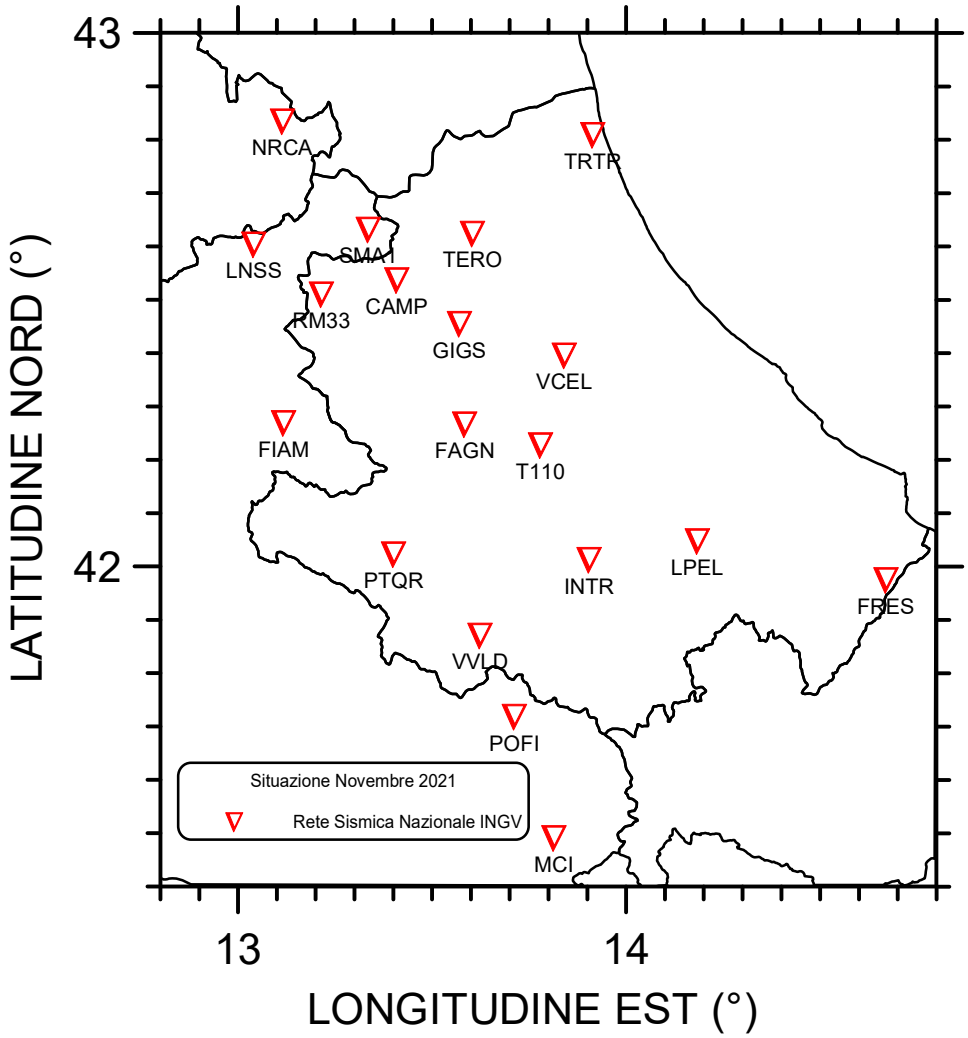
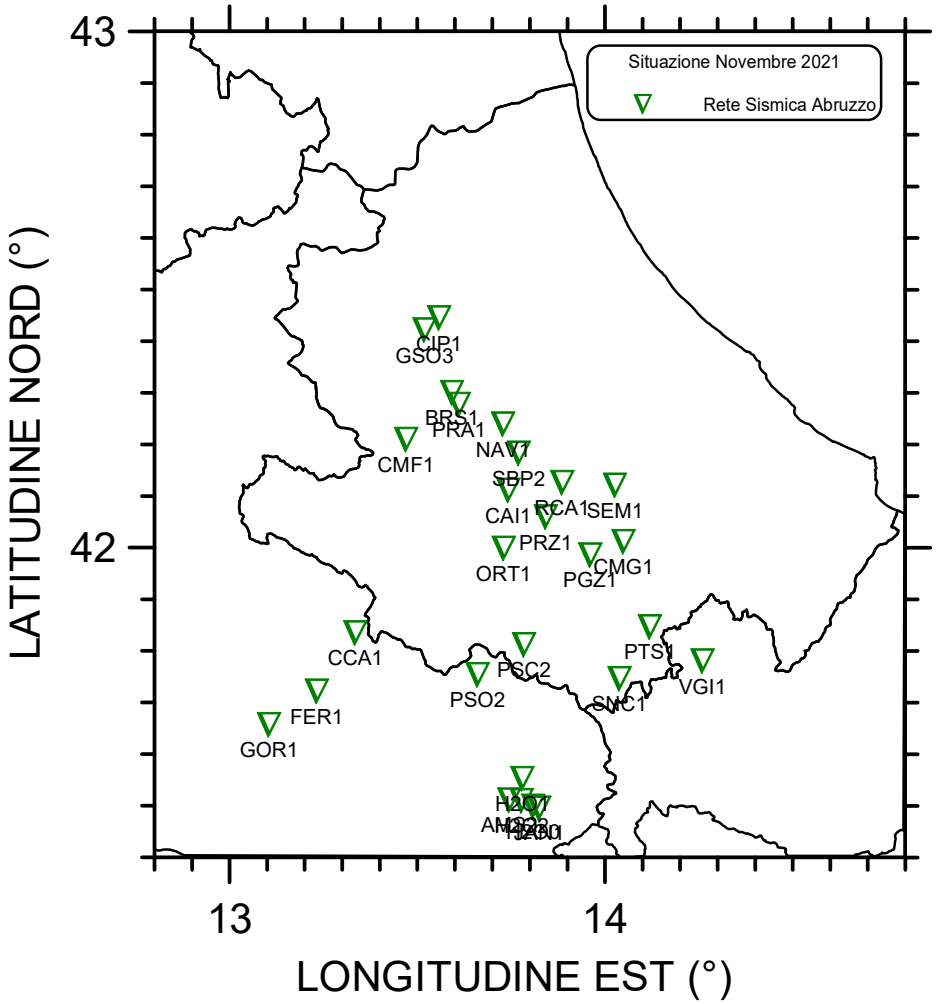
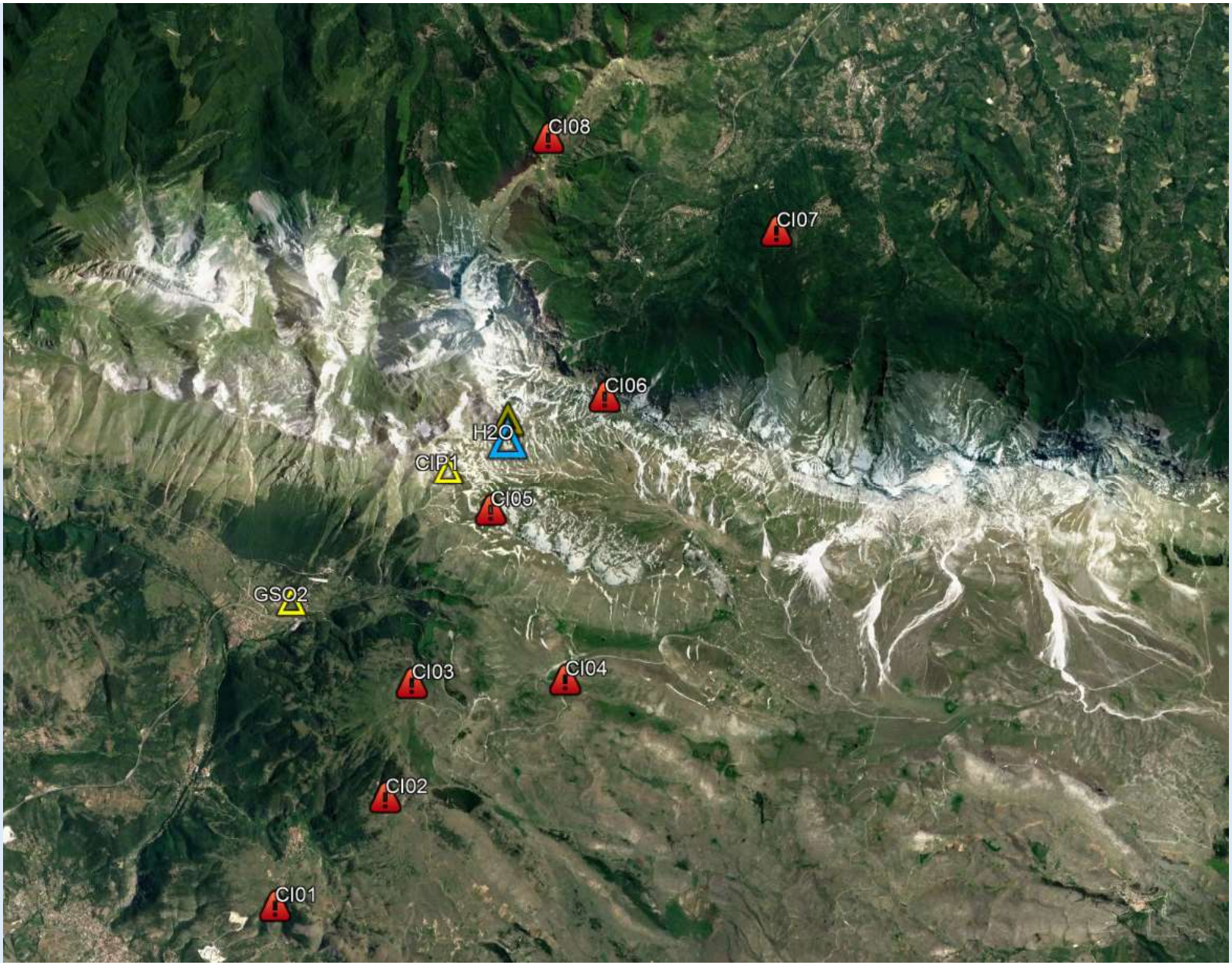
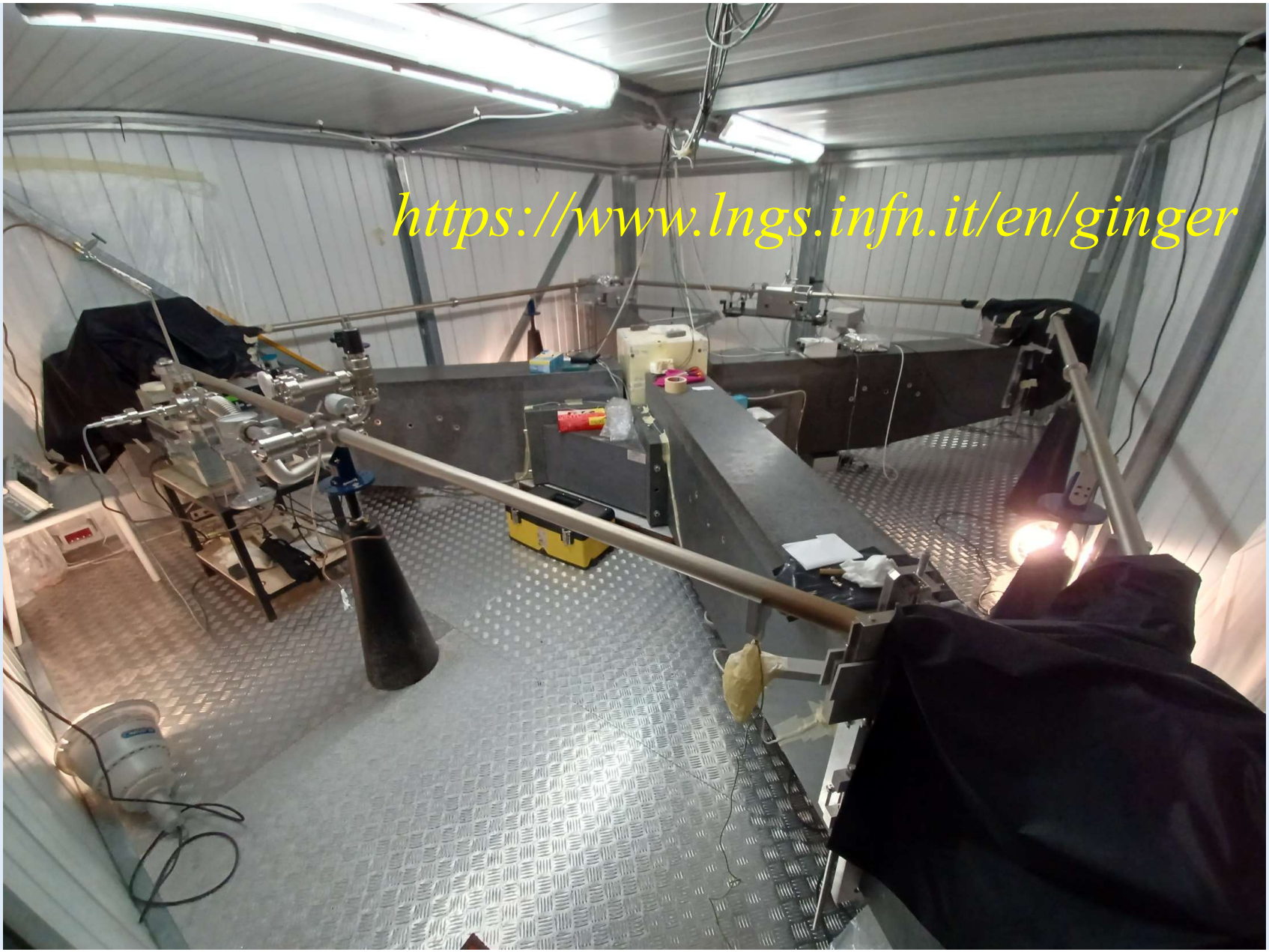


Fig. 1. Example of a drum record of microseismic activity at the end of February, 1992 in the Gran Sasso region.


43
42
13
14
LATITUDINE NORD (°)
LONGITUDINE EST (°)
NRCA
TRTR
LNSS
SMA1
TERO
CAMP
RM33
GIGS
VCEL
FIAM
FAGN
T110
PTQR
INTR
LPEL
FRES
VVLD
POFI
MCI
Situazione Novembre 2021
Rete Sismica Nazionale INGV

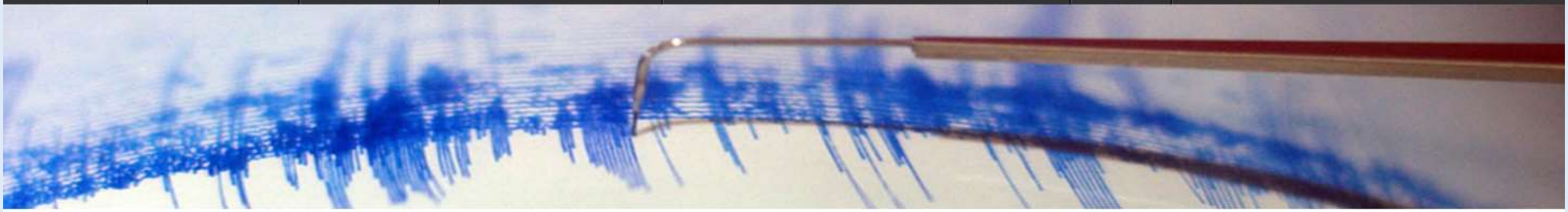

43
42
13
14
LATITUDINE NORD (°)
LONGITUDINE EST (°)
Situazione Novembre 2021
Rete Sismica Abruzzo
CIP1
GSO3
PRA1
CMF1
SBP2
CAI1
RCA1
SEM1
PRZ1
ORT1
PGZ1
CMG1
CCA1
PTS1
VGI1
PSC2
PSO2
SMC1
FER1
GOR1


CI08
CI07
CI06
H2O
CIP1
CI05
GSO2
CI03
CI04
CI02
CI01


https://www.lngs.infn.it/en/ginger

ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

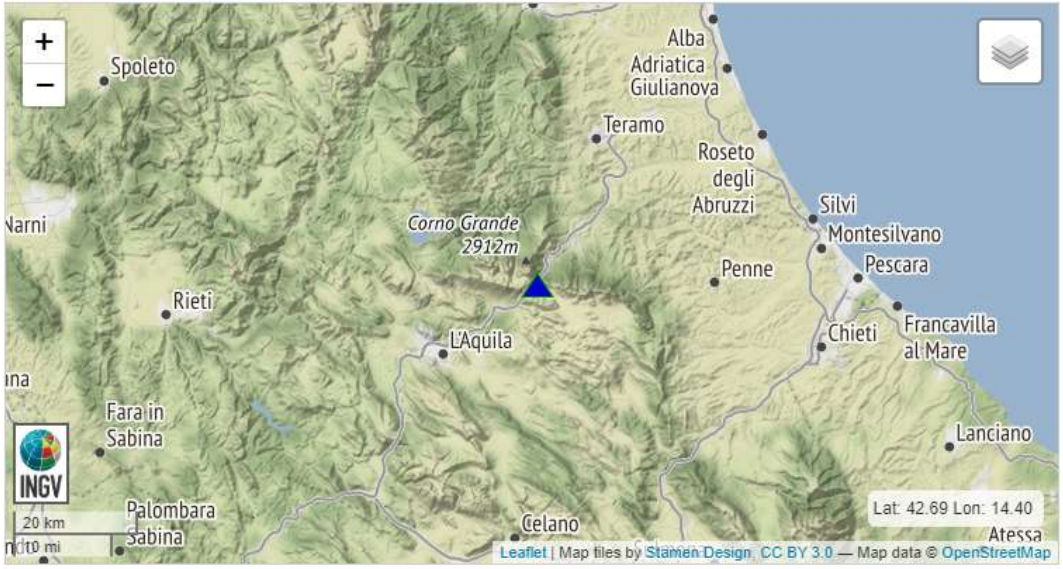
Earthquake list | Seismic networks | Real time data | Observatories and Centers | INGVterremoti | Site Guide | Contact



http://terremoti.ingv.it/instruments/station/GIGS#

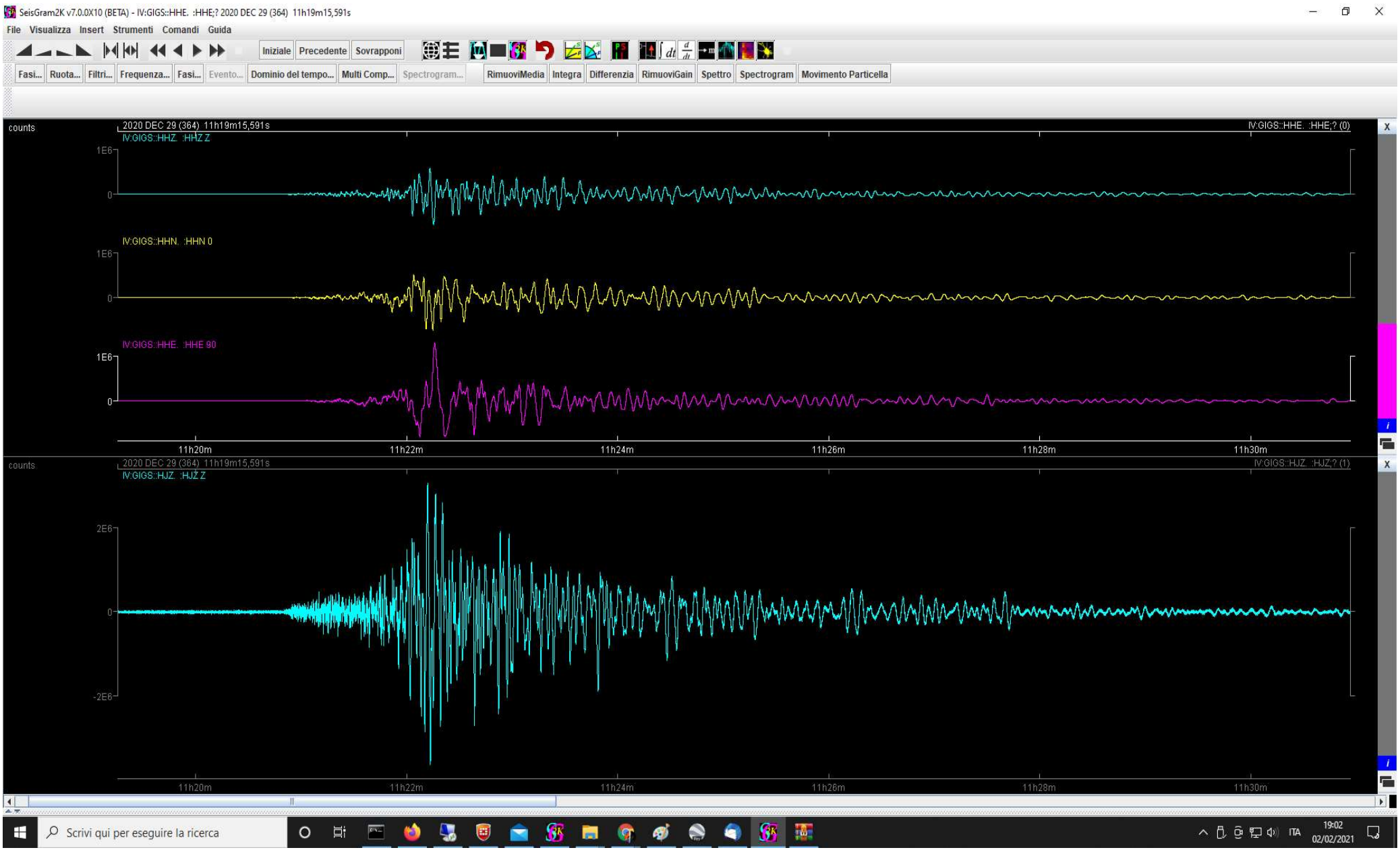
Seismic Station GIGS GIGS

Network: IV
Start Date: 2015-02-16T12:17:00
End Date: --
Latitude: 42.453167
Longitude: 13.572833
Elevation: 960
Download StationXML



http://webservices.rm.ingv.it/fdsnws/dataselect/1/query?network=IV&station=GIGS&channel=H??&start=2020-12-29T10:00:00&end=2020-12-29T13:00:00

HHZ, HHN, HHE + HJZ


SeisGram2K v7.0.0X10 (BETA) - IV:GIGS::HHE. :HHE;? 2020 DEC 29 (364) 11h19m15,591s
File Visualizza Insert Strumenti Comandi Guida
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11h28m
11h30m
Scrivi qui per eseguire la ricerca
ITA
19:02
02/02/2021

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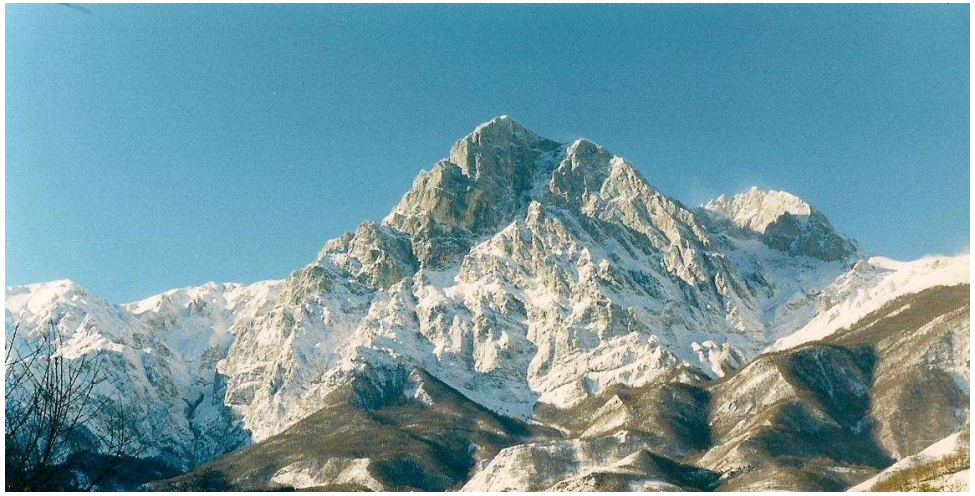
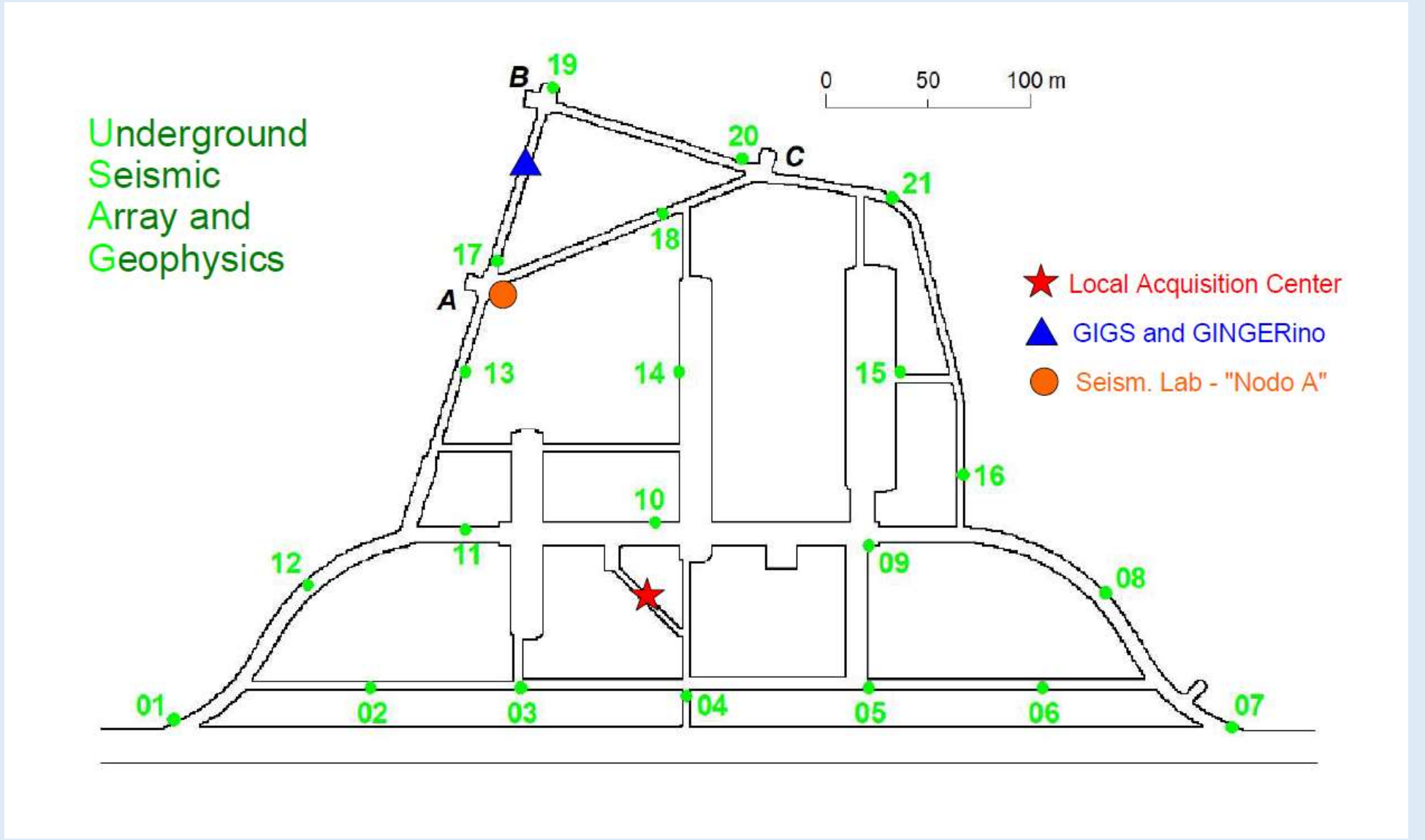
DI GEOFISICA E VULCANOLOGIA

INFN Istituto Nazionale di Fisica Nucleare



Creation of a multidisciplinary infrastructure dedicated to underground Geophysics at the INFN LNGS and a geophysics laboratory for the study of seismic precursors

1
Seismic Array Underground


Underground
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Geophysics
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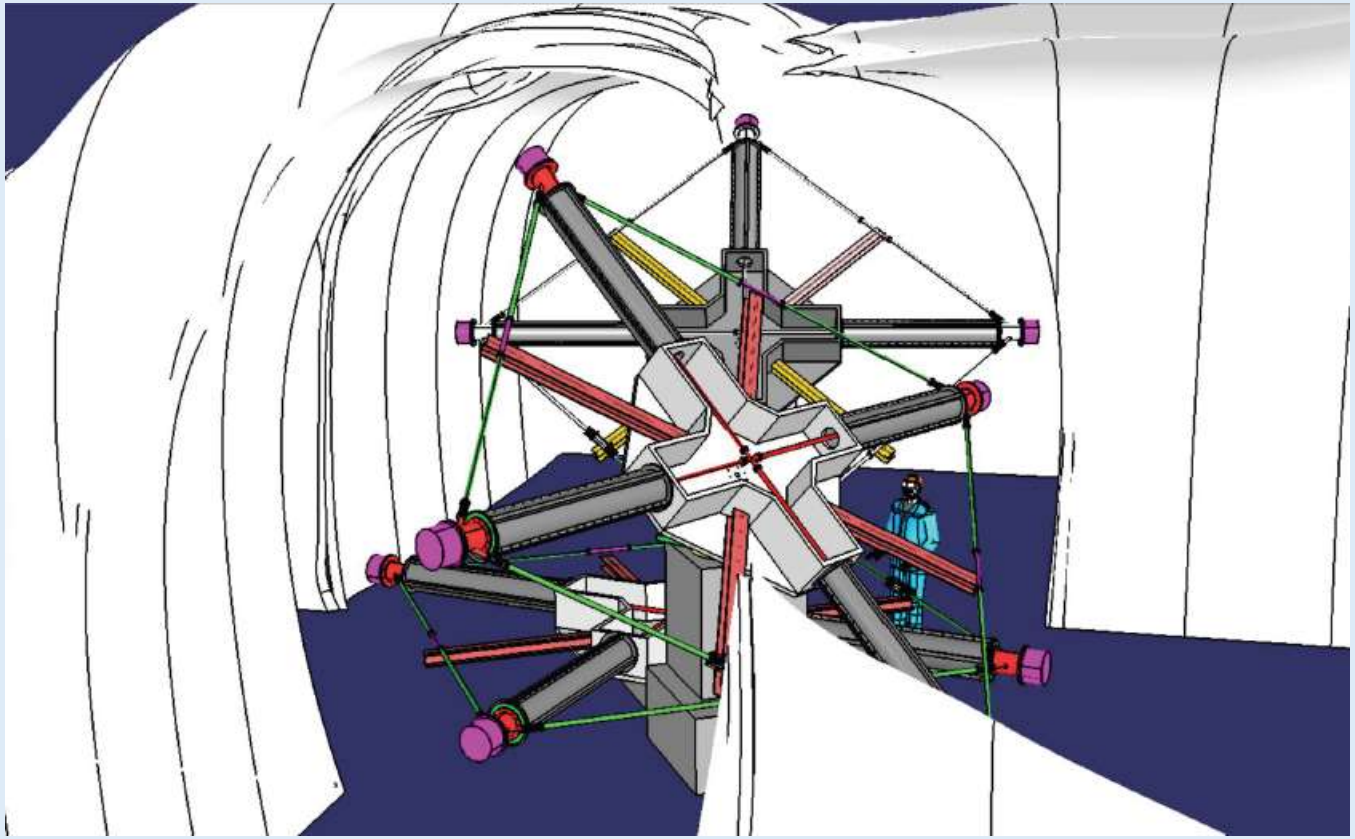
Local Acquisition Center
GIGS and GINGERino
Seism. Lab - "Nodo A"

Site n. 06

Seismic Array

- Geometry (radar)
- Signals not impulsive
- Wavefield composition
- Correlation analysis
- Dispersion curve
- Staking
- S/N ratio
- Polarization analysis

2
Experiment: GINGER



Geodetic-Geophysical topics
(INFN-INGV cooperation)

1. Study of high frequency variations of Earth Rotation Parameters
   - Tidal variations of polar motion
   - High frequency UT1 variations (Oceans & Atmosphere tides)
2. Study of high frequency Earth's axis nutation
   - Forced nutations
   - Free core nutation
3. Monitoring high frequency local tilt and Solid Earth Tides
4. Rotational seismology

3
Underground Seismometry Laboratory

Nodo A

«huddle test»
GIGS
360s + accelerometer

4 iGrav

1 nanoGal – 0.01 nm/s2

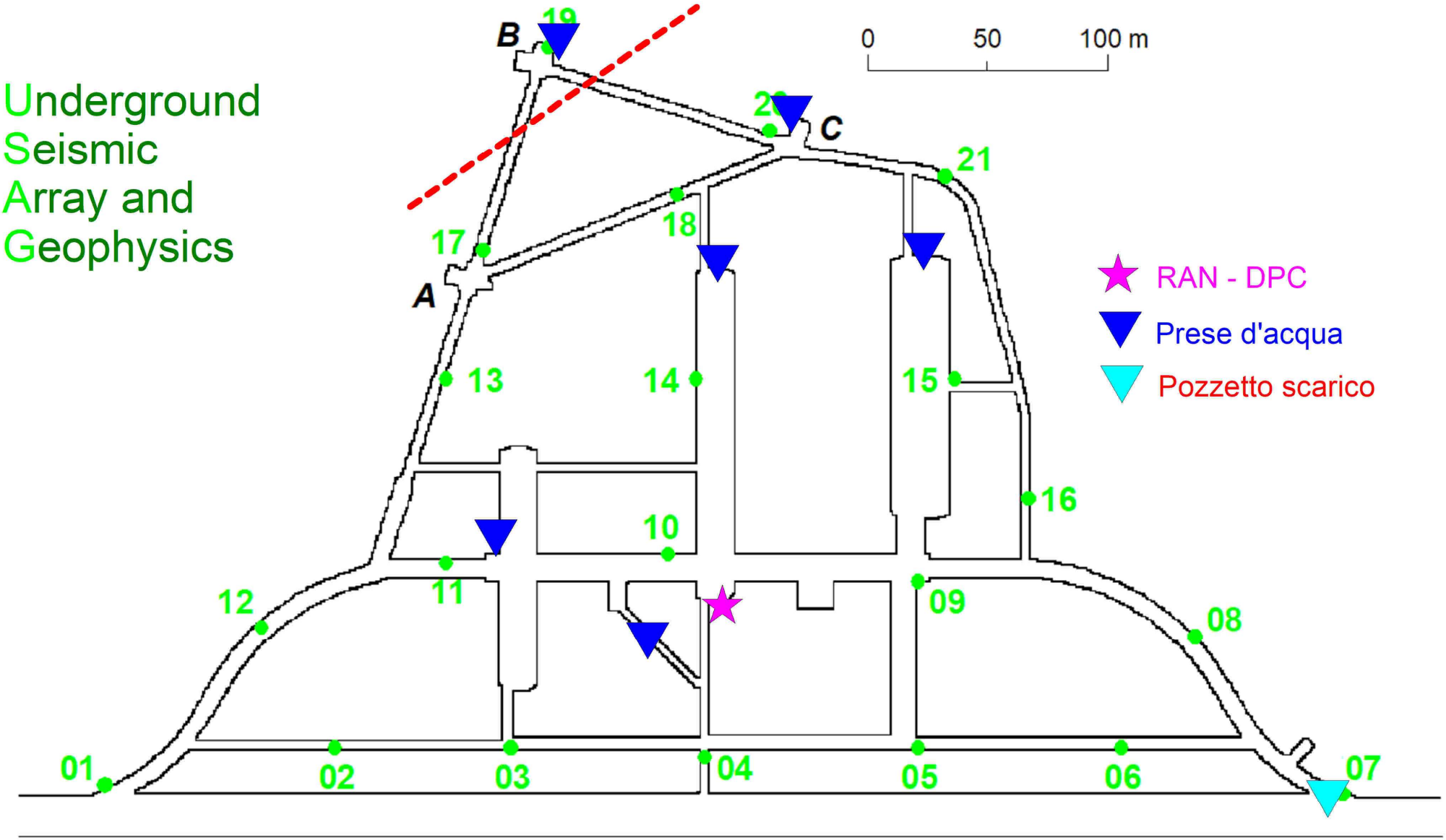
5:30 PM

Gravimetry in the Italian area: future developments and perspectives 30m

In Italy, gravimetry is largely carried out since '80 to study and monitoring active volcanoes of central-southern and insular Italy, but was not extensively applied in seismic areas, except in Central Italy, where gravity measurements have been performed since 2018, aimed to study the dynamics of the main tectonic processes, also including absolute stations already present and measured in the area for different purposes. Here we present the state-of-the-art of the gravimetry in Italy and the developments and perspectives. Specifically, in order to lay the foundations for a multidisciplinary approach to natural risk assessment, a large-scale gravity network in Italy, which in the most advanced development will consist of about 10 sites, homogeneously distributed throughout the country, is under realization. The network will allow for determining the temporal variations of the long-term and long-wavelength gravity field in seismic and volcanic areas. The sites will be equipped with absolute or relative gravimeters in continuous or pseudo-continuous recording (e.g. 1 measurement every week). For this purpose, superconducting gravimeters and atomic and ballistic absolute gravimeters will be used, the only instruments capable of providing a highly precise and stable signal even in the long term. This network, will supplements the newly established National Reference Gravimetric Network (G0) and the National Gravimetric Service in the planning stage

Speaker: Filippo Greco (INGV-OE)

5
Physical and chemical monitoring of groundwater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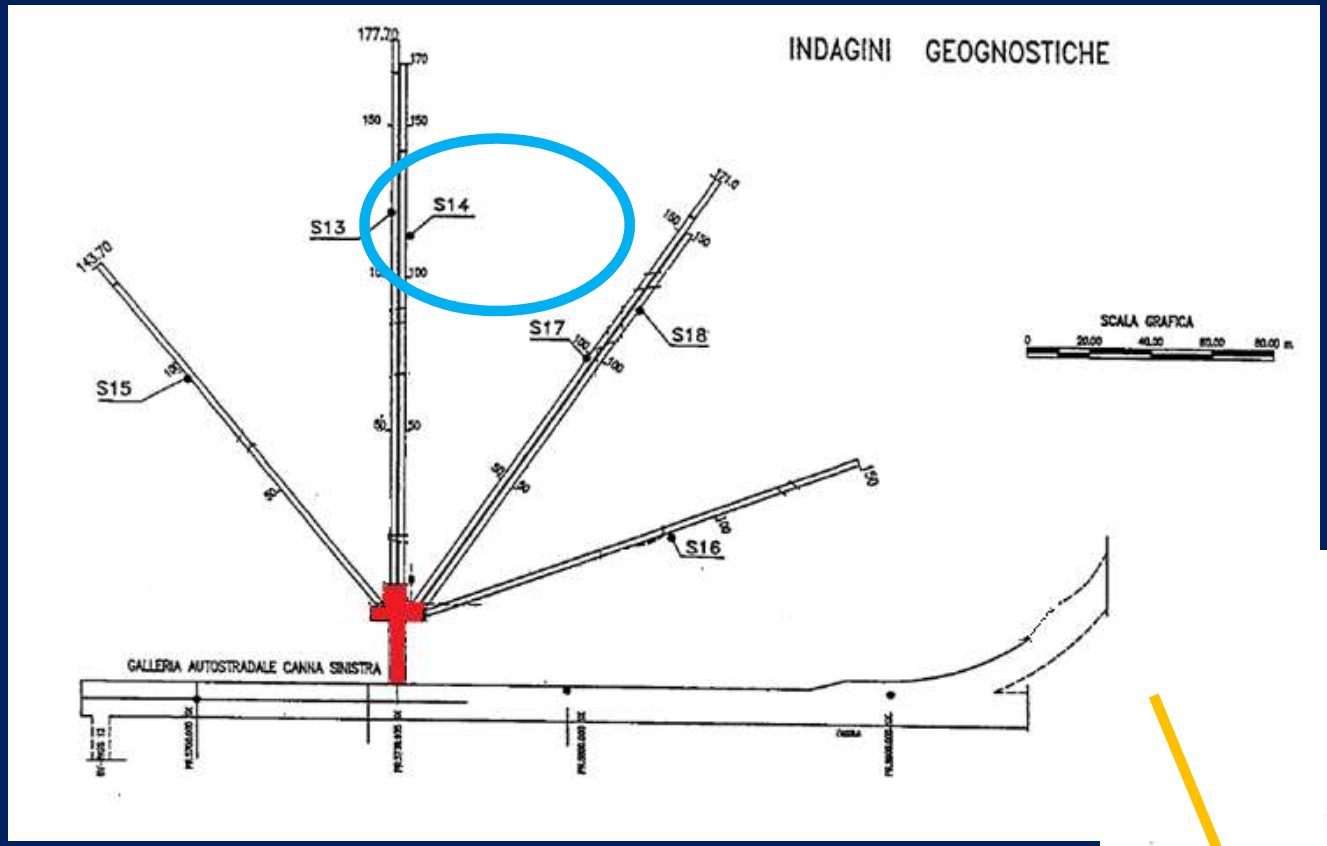
Prese d'acqua
Pozzetto scarico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143.70
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S16
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S18
SCALA GRAFICA
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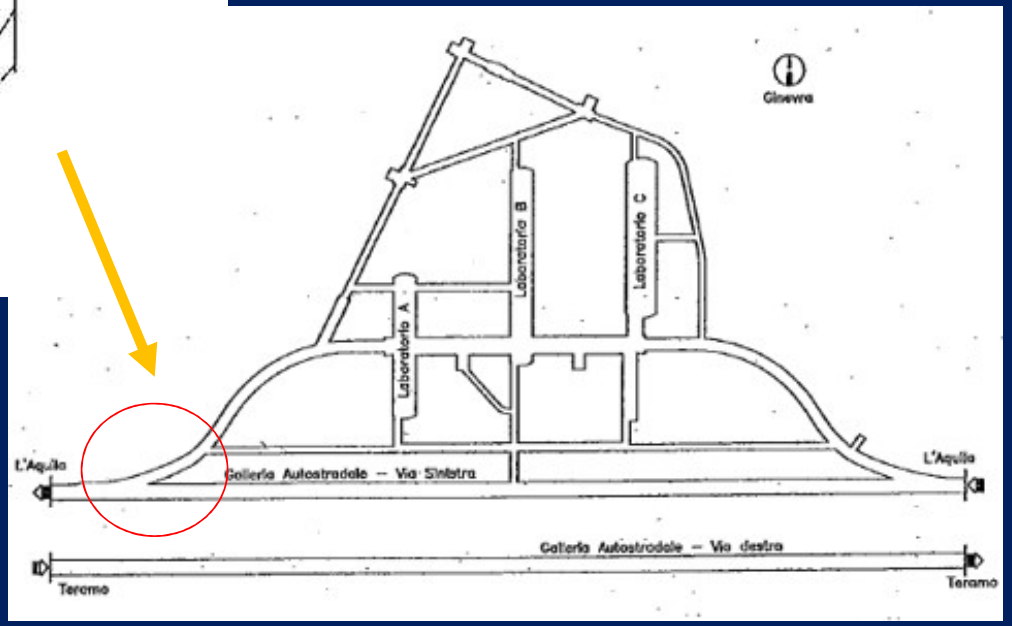
GALLERIA AUTOSTRADALE CANNA SINISTRA


Ginevra
Laboratorio A
Laboratorio B
Laboratorio C
L'Aquila
Galleria Autostradale – Via Sinistra
L'Aquila
Galleria Autostradale – Via destra
Teramo
Teramo

https://www.nature.com/articles/s41598-018-34444-1

www.nature.com/scientificreports

OPEN

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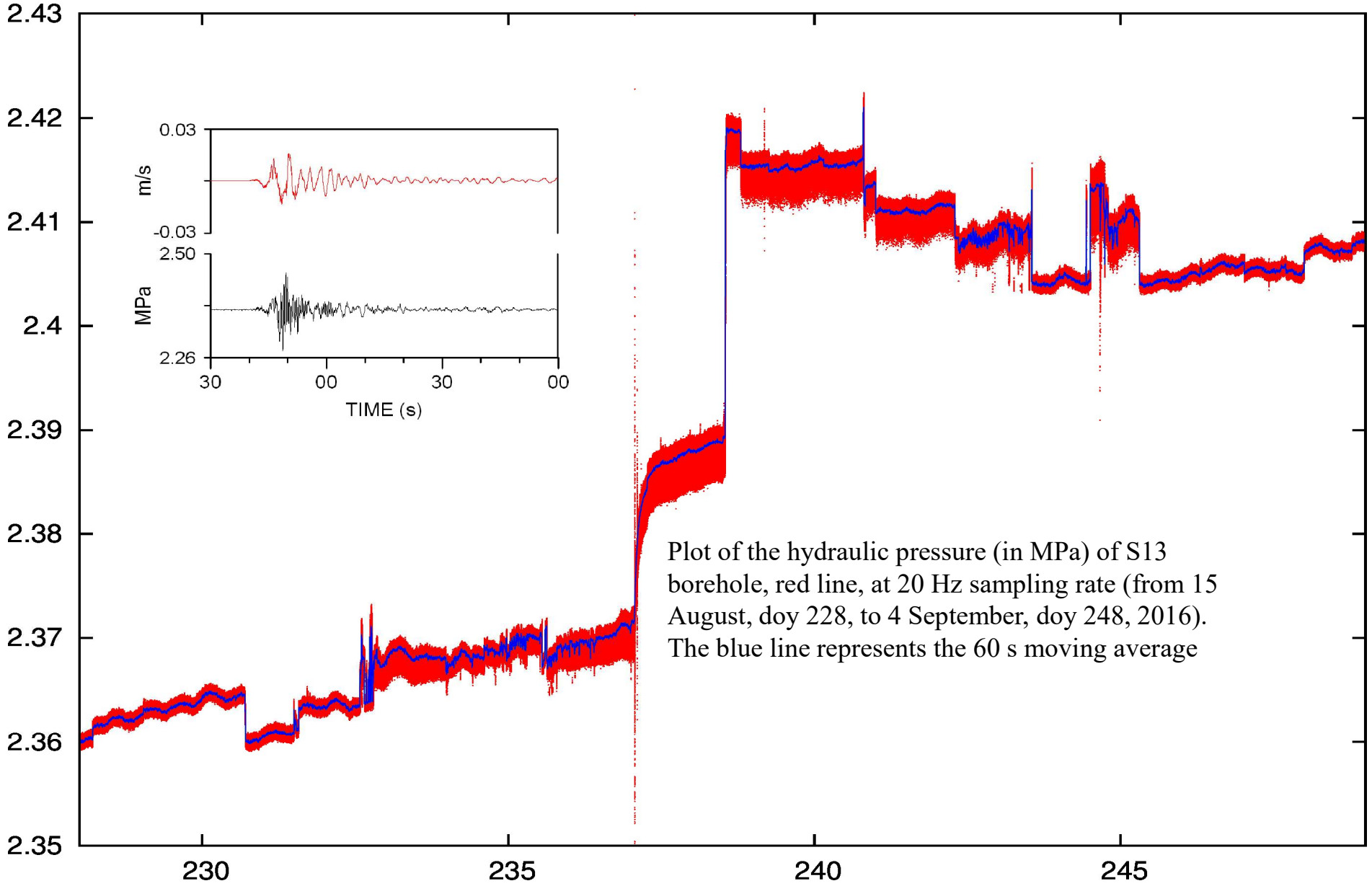
Accepted: 12 October 2018
Published online: 29 October 2018

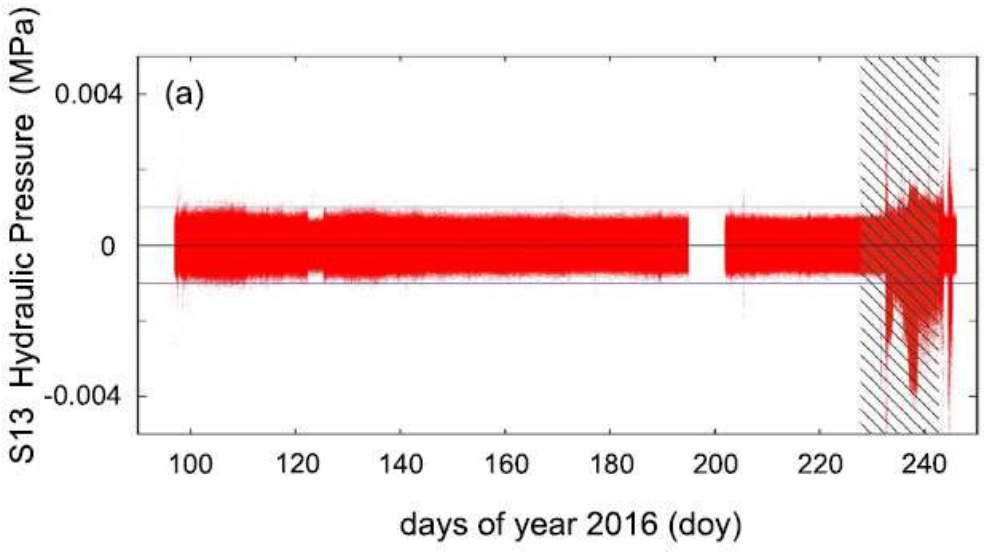
A record of changes in the Gran Sasso groundwater before, during and after the 2016 Amatrice earthquake, central Italy

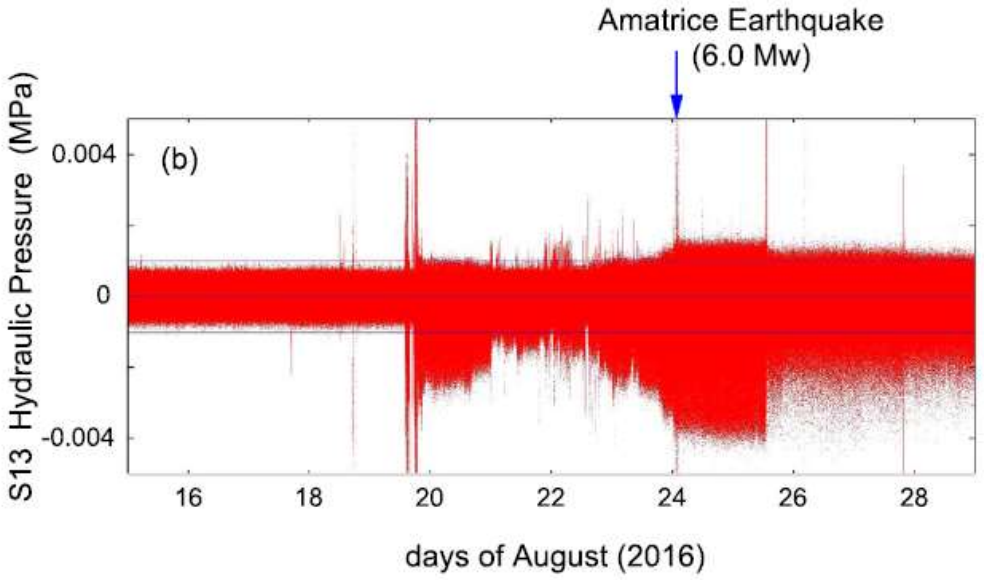
Gaetano De Luca[1], Giuseppe Di Carlo[2] & Marco Tallini[3]

We performed continuous recordings (May 2015 – January 2017) of hydraulic pressure and electrical conductivity of groundwater in the 190 m-long horizontal S13 borehole drilled next to the deep underground laboratories of Gran Sasso (*LNGS-INFN*), located in the core of the Gran Sasso carbonate aquifer (central Italy) at a distance of about 39 km south-eastward from the 24 August 2016 Amatrice earthquake (6.0 M_w) epicenter. Using a 3-channel, 24-bit ADC we achieved a sampling rate of groundwater physical properties up to 50 Hz for each channel. We focused on the analysis of data recorded before, during and after the Amatrice earthquake, describing and discussing in detail the evidence for significant hydraulic pressure and electrical conductivity anomalies recorded before the main shock. We identified unambiguous signals in the hydraulic pressure data starting on 19 August, i.e. five days before the 24 August mainshock. A more careful analysis allowed us to detect the inception of a weak change up to 40 days before the Amatrice earthquake and a significant variation in the electrical conductivity data about 60 days before. The data revealed highly dynamic aquifer behaviour associated with the uprising of geogas probably related to the preparation stage of the Amatrice earthquake.



Plot of the hydraulic pressure (in MPa) of S13 borehole, red line, at 20 Hz sampling rate (from 15 August, doy 228, to 4 September, doy 248, 2016). The blue line represents the 60 s moving average

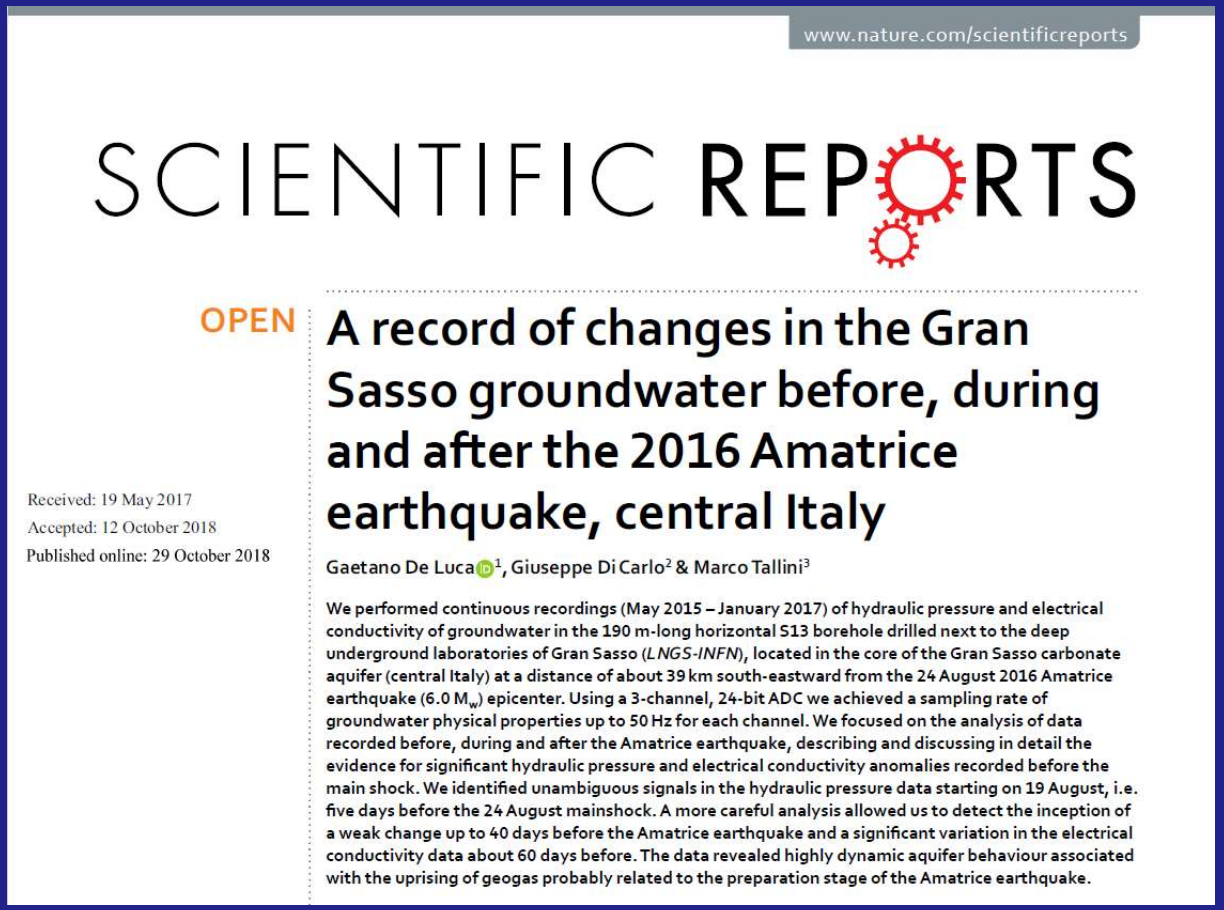




(a) Detrended of hydraulic pressure of S13 borehole from April to August 2016.

(b) Detrended of hydraulic pressure of S13 borehole from 15 (doy 228) to 29 August 2016 (doy 242), shaded rectangle in (a). The blue arrow in the top of (b) represents the Amatrice earthquake occurrence. In the period from May 2015 to March 2016 we did not observe any variations.

https://www.nature.com/articles/s41598-018-34444-1



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SCIENTIFIC REPORTS

OPEN

A record of changes in the Gran Sasso groundwater before, during and after the 2016 Amatrice earthquake, central Italy

Received: 19 May 2017
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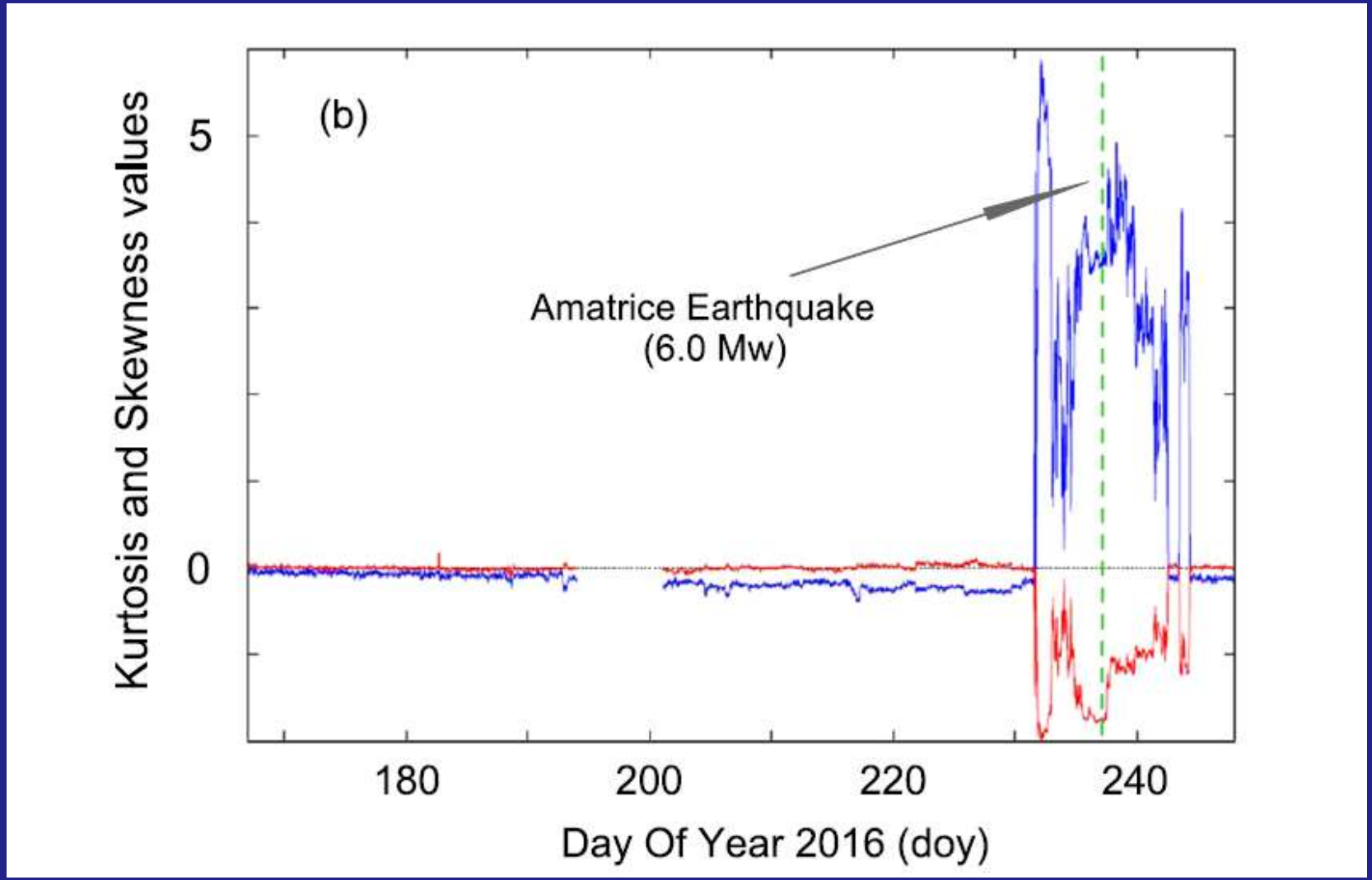
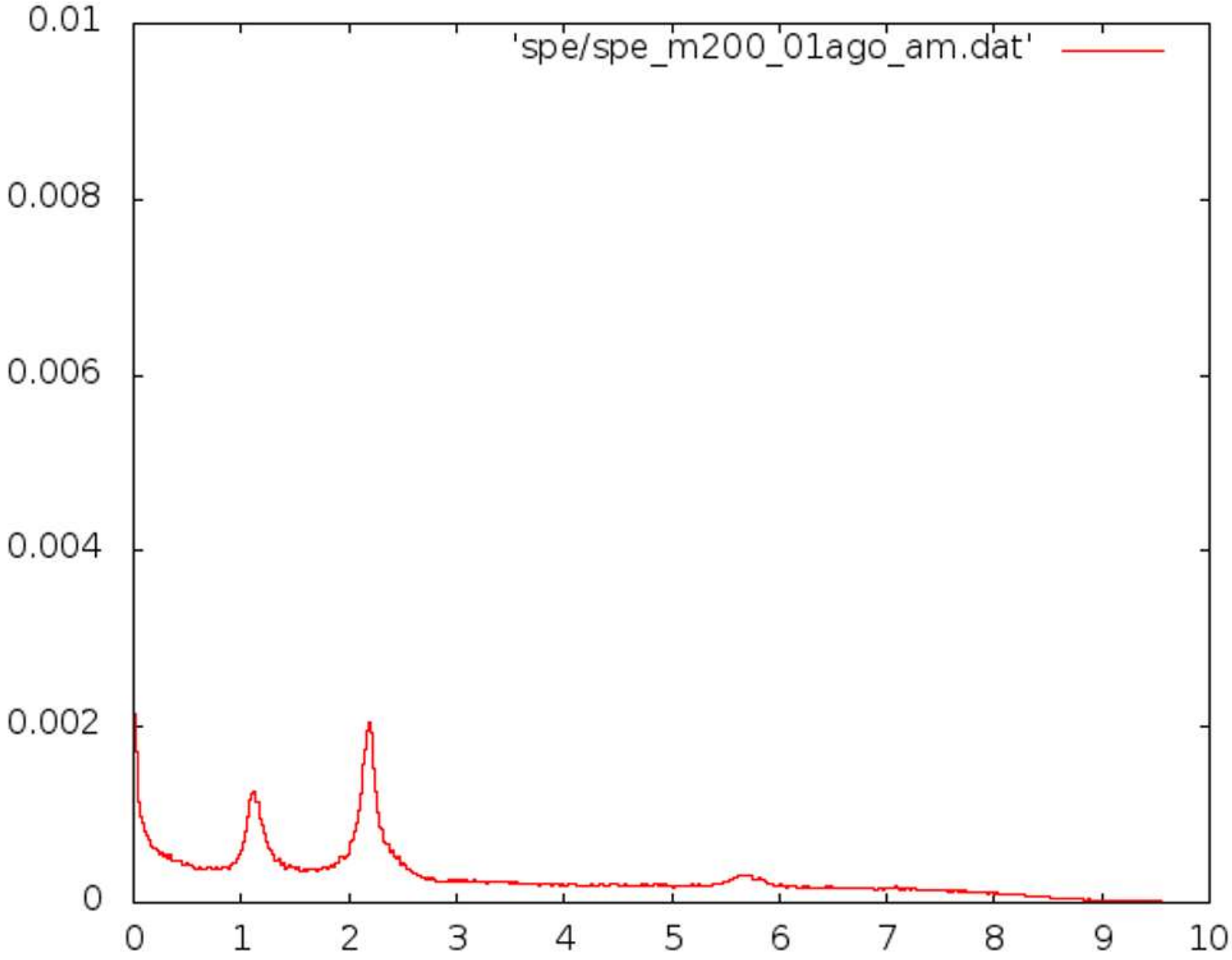
Thank you ☺



skewness $m_3/(m_2)^{3/2}$ kurtosis $(m_4/m_2^2 - 3)$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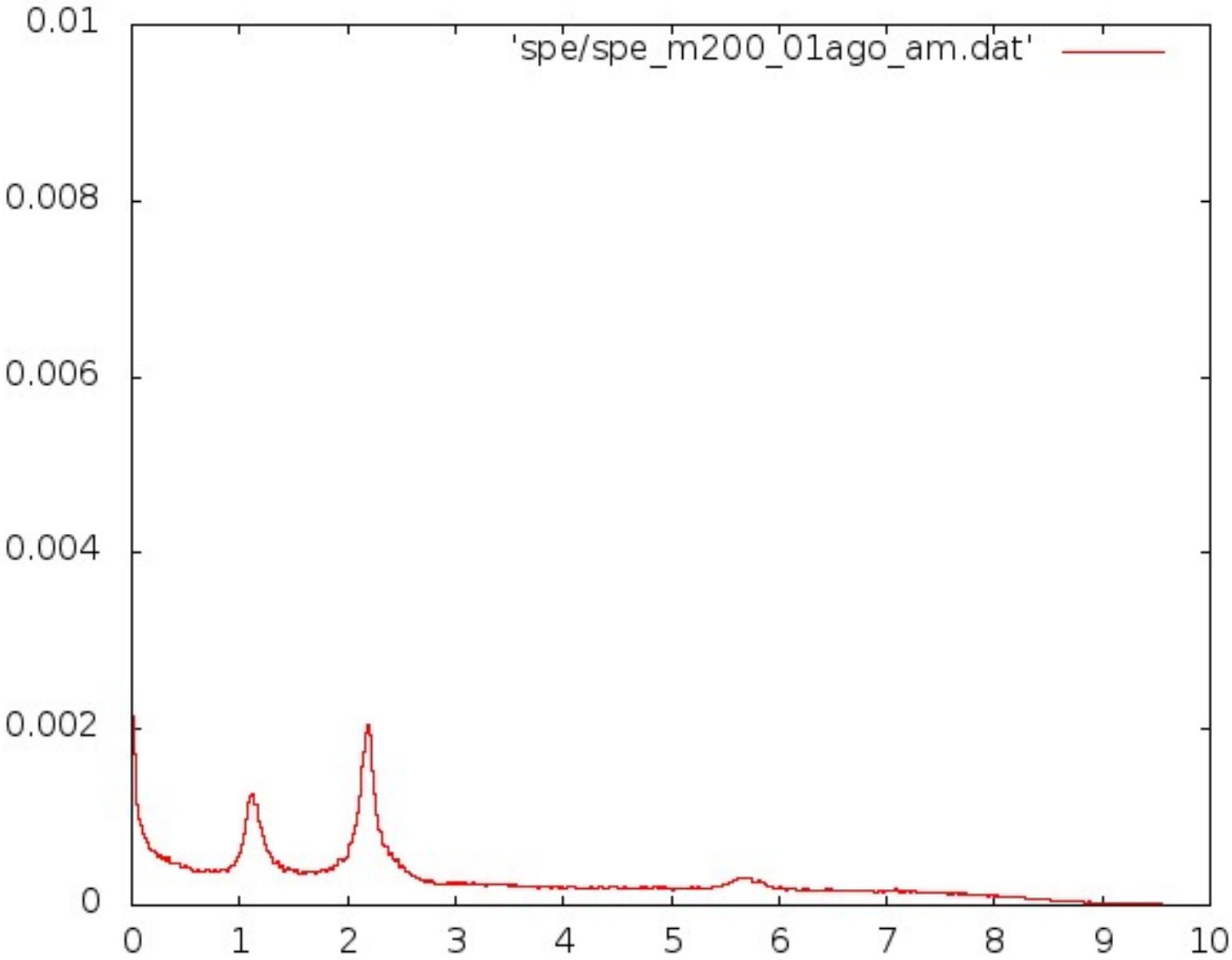
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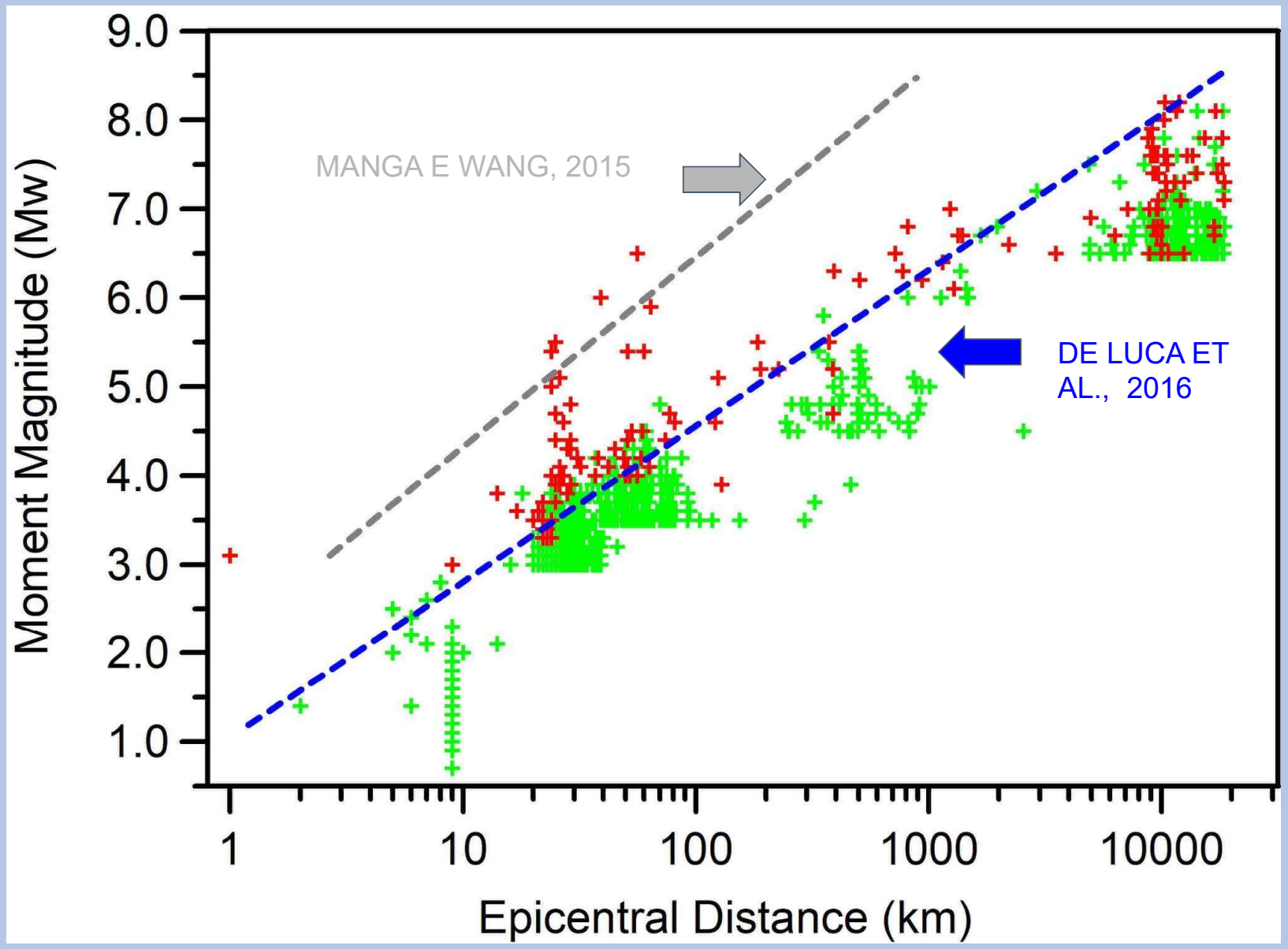

EVENTI NON RILEVATI DALL' ACQUIFERO

EVENTI RILEVATI DALL' ACQUIFERO

Fuso Orario: UTC | Dal 01-08-2016 al 23-08-2016 | Magnitudo: tutte | Punto: (42.6304, 13.2893) - Raggio: 5 km | Personalizza Ricerca | Mappa

Visualizzati 10 terremoti (Ordinamento Tempo Decrescente)

Esporta lista (UTC)

Data e Ora (UTC)	Magnitudo	Zona	Profondità	Latitudine	Longitudine
2016-08-19 13:18:49	ML 1.2	5 km E Amatrice (RI)	15	42.61	13.35
2016-08-09 10:22:23	Md 1.2	3 km SW Amatrice (RI)	13	42.61	13.25
2016-08-08 02:06:13	ML 1.0	2 km E Amatrice (RI)	13	42.64	13.31
2016-08-07 18:04:01	ML 1.4	3 km SW Amatrice (RI)	12	42.61	13.26
2016-08-02 19:37:00	ML 0.7	3 km NW Amatrice (RI)	5	42.65	13.28
2016-08-02 11:25:38	ML 1.5	2 km W Amatrice (RI)	13	42.63	13.26
2016-08-01 21:04:39	ML 1.5	5 km SW Amatrice (RI)	11	42.59	13.27
2016-08-01 06:32:19	ML 0.9	5 km E Amatrice (RI)	8	42.61	13.34
2016-08-01 04:12:11	ML 1.3	4 km SW Amatrice (RI)	11	42.60	13.27
2016-08-01 04:08:31	ML 0.6	2 km SW Amatrice (RI)	14	42.61	13.27