EWG Dams and Earthquakes

ITCOLD Working Group "Observed behaviour of Italian dams under historical earthquakes "

Rosella Caruana Adriano De Sortis

Roma 6,7 Febbraio 2017

Observed behaviour of Italian dams under historical earthquakes

The presentation reports the results of the activities carried out by the ITCOLD Working Group ”**Observed behaviour of Italian dams under historical earthquakes**“.

The ITCOLD Working Group is composed as follows:

Angelica Catalano (Chairman), Rosella Caruana, Federica Del Gizzi, Adriano De Sortis, Giovanni Marmo, Fabio Sabetta, Massimo Rescigno, Alfredo Rossi

Summary

- Preliminary remarks: the Dam Authority post-earthquake procedure
- Observed behaviour during historical earthquakes:
  - Selection of dams for the historical survey
  - Check-list
  - Observed seismic effects
- Conclusions

Dam control - post-earthquake procedure

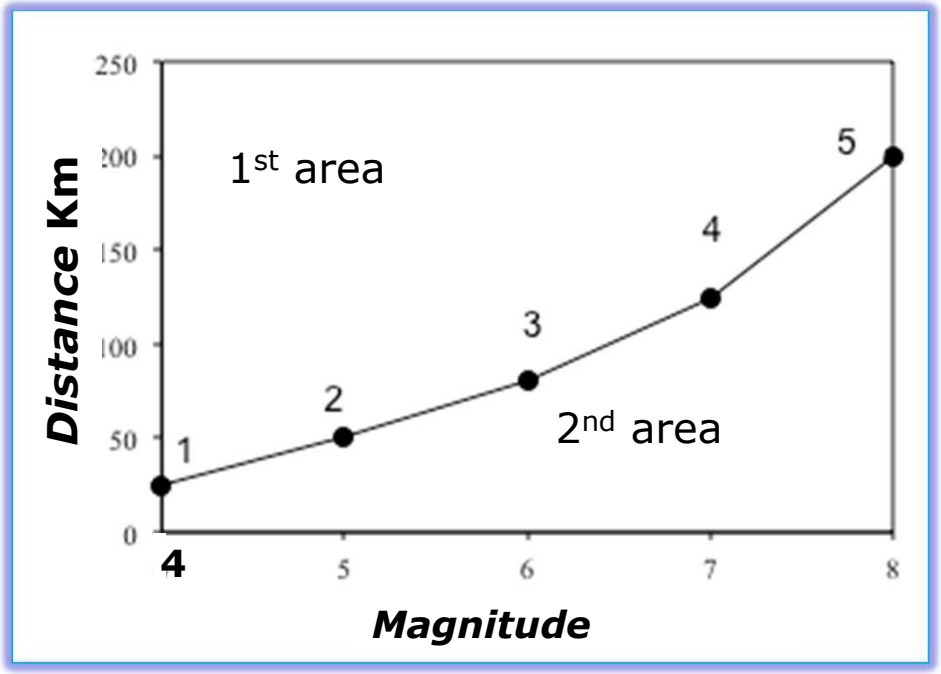
The procedure

Controls for events of magnitude M≥ 4

- Dams inside a specific area depending on the magnitude of the earthquake
- Dams near the area if with effects at the dam site
- Controls: immediate visual, instrumental measurements
    - Dam Engineer ⇨ Report of dam safety

Dam control

- First area : no control except for the case that the earthquake has been felt at the site of the dam
- Second area: immediate inspections and all essential measures for safety



Observed behaviour of Italian dams under historical earthquakes – Selection of dams

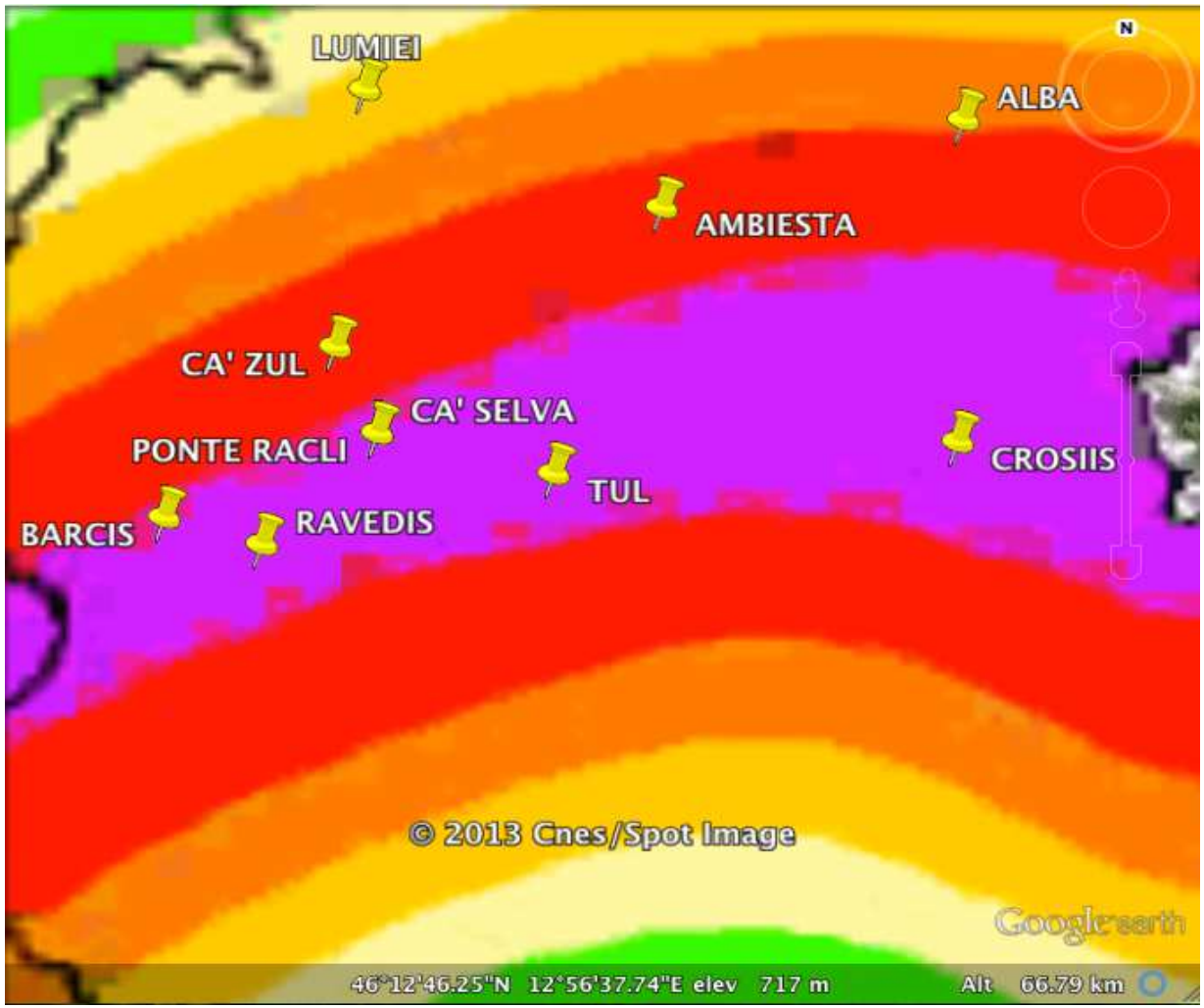
- First step: **selection** of dams to be studied (from 539 to 100)
- Method: selection of the cases with highest seismic input
- Possible criteria to compare the dams:

1. design seismic action reported in the current Italian Code
2. collection of the seismic Intensities (DBMI04 database) during past earthquakes
3. estimation of shaking parameters (Maximum Acceleration) during past earthquakes

Observed behaviour of Italian dams under historical earthquakes – Selection of dams

Criterion 1: Design seismic action

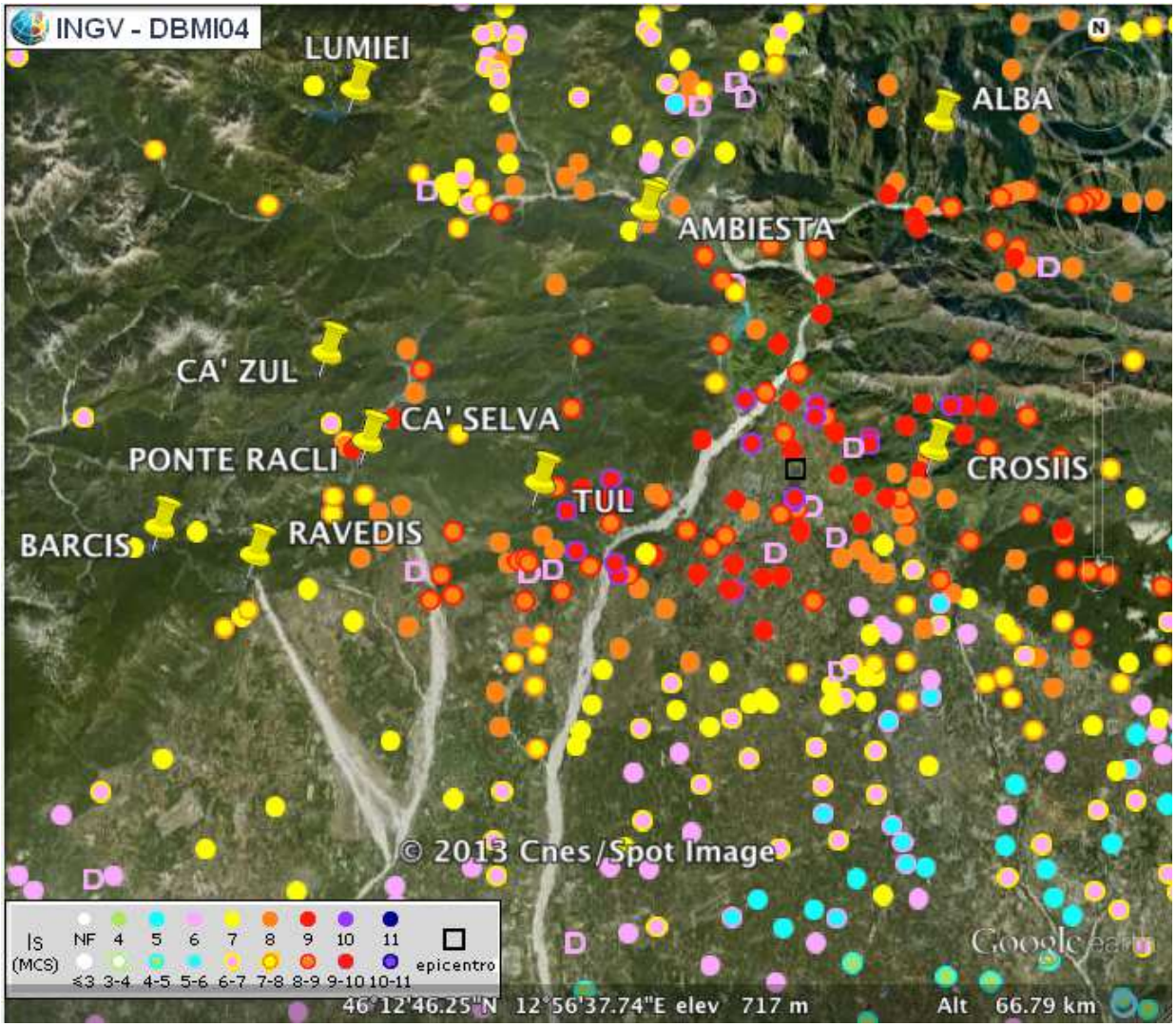
- The national territory is divided into cells
- For each vertex the peak ground acceleration (PGA) is defined (probabilistic seismic hazard)
- This approach does not consider if a dam has been really involved in historical earthquakes



Observed behaviour of Italian dams under historical earthquakes – Selection of dams

Criterion 2: Macroseismic Intensity

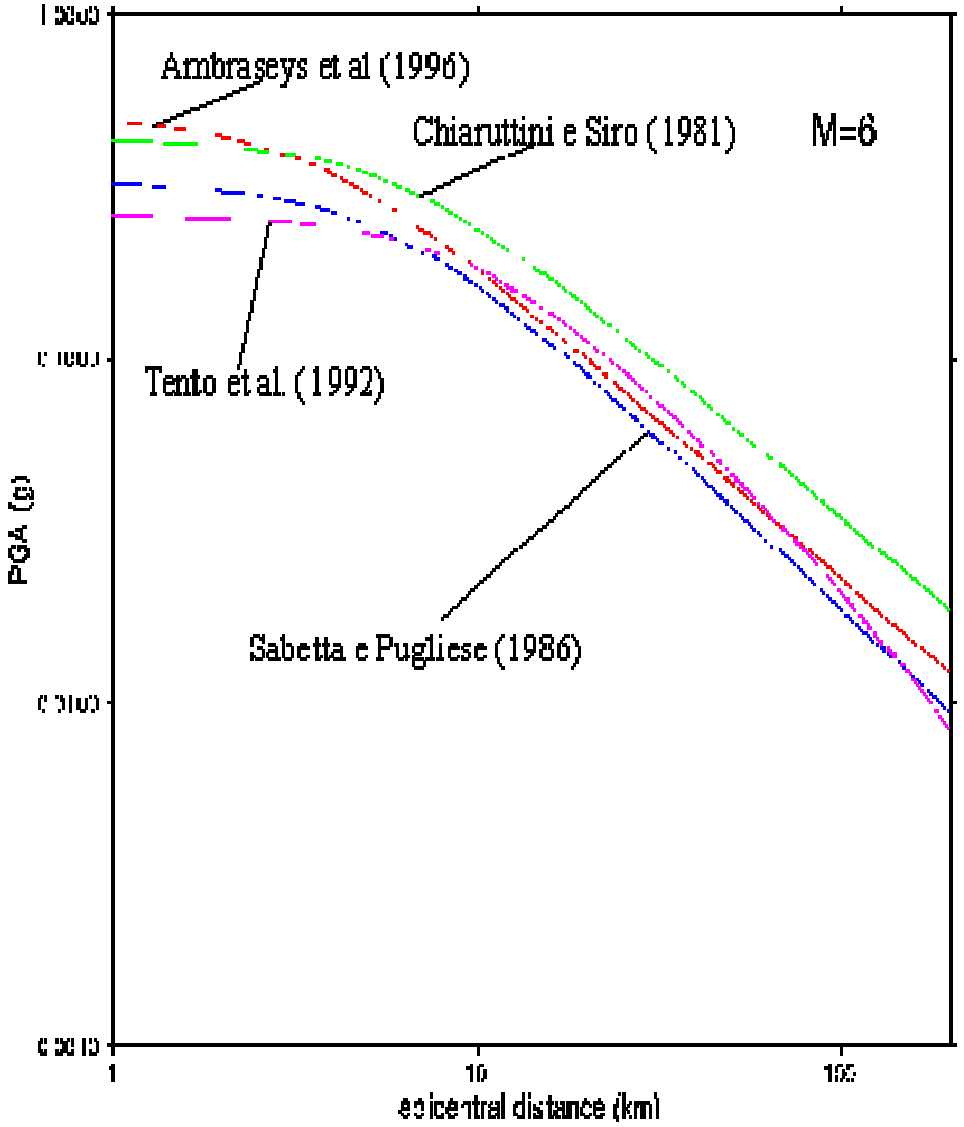
- DBMI04 database collects the **Intensity** for several locations (municipalities, villages)
- Is ≥ VI at a maximum distance of 10 km
- 77 dams selected



Observed behaviour of Italian dams under historical earthquakes – Selection of dams

Criterion 3: Attenuation Laws

- CPTI04 catalogue collets the **Magnitude** for each earthquake
- From Magnitude and **distance** a strong motion parameter can be estimated
- Attenuation law: Log (PGA) = -1.845 + 0.363*M – Log $(R^2 + 5^2)^{1/2}$
- PGA ≥ 0.07 g (corresponding to $I_{MCS} \approx$ VI).
- 100 dams selected



Observed behaviour of Italian dams under historical earthquakes – Selection of dams

Dam	Is	PGA (Is)	PGA (atten. g)	*min PGA (g)*	*max PGA (g)*	PGV (cm/s)
CORFINO	10	0.450	0,325	*0,210*	*0,503*	18,8
CASTEL S. VINCENZO	8	0.178	0,312	*0,201*	*0,483*	25,8
CROSIIS	9-10	0.357	0,302	*0,195*	*0,468*	17,1
MURO LUCANO	8	0.178	0,250	*0,161*	*0,387*	20,3
VASCA OGLIASTRO	6-7	0.089	0,241	*0,156*	*0,373*	18,2
BASTIA	9	0.283	0,236	*0,152*	*0,366*	16,9
VILLA PERA	7-8	0.142	0,221	*0,143*	*0,342*	12,4
MULINELLO	6-7	0.089	0,220	*0,142*	*0,341*	11,6
ACCIANO	8-9	0.225	0,204	*0,132*	*0,316*	10,5
FIUMARA GRANDE	6-7	0.089	0,196	*0,127*	*0,304*	9,8
MONTAGNA SPACCATA 3	8	0.178	0,193	*0,125*	*0,299*	13,1
MONTAGNA SPACCATA 1	8	0.178	0,188	*0,121*	*0,291*	9,3
SAN PIETRO	7	0.112	0,187	*0,121*	*0,290*	15,1
MONTAGNA SPACCATA 2	8	0.178	0,185	*0,119*	*0,287*	9,1

Criterion 2

Criterion 3

Study of the dams

- 100 dams selected → each dam describes an experience
- → Each dam has over than 1 event higher than 0,07 g
- → Total examined events are much more than 100

For each dam inspection data and information (stored) in archives and at dam site →

A **Check List** was developed to collect information

Check-list

	Instability of dam body, liquefaction, uncontrolled seepage
Effects on the shores of reservoir	Stability of the banks, description of the landslide, interference with the dam body, interferences with the gates and accesses to the dam
complementary and auxiliary structures	the gates, put mechanical elements out of use
Check after earthquake	Check before 2002 – check after 2002 extraordinary procedure

CHECK LIST FOR	
Data of dam	
Seismic event	Date epic pga(of ea
Check after earthquake	Chec 2002
Effects on dam and soil foundation	Insta liquefaction, uncontrolled seepage, possible overflow, breakage of sealing element
Effects on discharges and on complementary and auxiliary structures	Mechanical blocking of the moving elements, mechanical instability of the gates, put mechanical elements out of use
Effects on the shores of reservoir	Stability of the banks, description of the landslide, interference with the dam body, interferences with the gates and accesses to the dam

	ongitude, Elevation of top ight of dam, year of on, strategic structure or
	ent, distance from tre lmcs(DBMI04), pgv, , level of reservoir at the time hquake
	before 2002 – check after
Effects on dam body and soil foundation	instability of dam body, g of joints, breakage sealing element of joints, breakage of drainage system, screen break in foundation, overflow, breakage of the monitoring system
Effects on discharges and on complementary and ancillary structures	Mechanical blocking of the moving, mechanical instability of the gates, mechanical elements out of use
Effects on the shores	Stability of the banks, description of the landslide, interference with the dam body , interferences with the

Observed Seismic Effects

Results

In some cases we did not find data; especially for the most early seismic events.

The examined cases showed that:

1) In most cases dam and power plant are not influenced by seismic event;

2) Two earth dams showed damages resulting in needed repair work: Ogliastro and Acciano

- Ogliastro basin: Lesions of the bituminous facing with consequent leakage of water through the dam body;
- Acciano dam: Longitudinal lesions parallel to the top of the dam together with transverse lesions;

3) Piana degli Albanesi masonry gravity dam:

- Release of water through the structure without compromising the stability of the dam;

4) For power plant, some damages that often didn't prevent normal functioning;

The observed seismic effects

The first group of dams

(N.A = NO DATA FOUND, N.F. = REGULAR OPERATION, S.L.O. = LIMIT STATE OF OPERATION, S.L.D. = LIMIT STATE OF DAMAGE, S.L.V. = LIMIT STATE OF LIFE SAFETY, S.L.C.= LIMIT STATE OF COLLAPSE)

DAM	Date of seismic event	Distance	Msp	pga(g)	Imcs	PGV	End of construction	Effects observed
BARREA	07/05/1984	11,6	5,7	0,129	8	6,1	1951	N.F.
ANCIPA	31/10/1967	11,5	5,4	0,108	7,5	4,8	1953	N.F.
SELVA	07/05/1984	9,5	5,7	0,152	7	9,9	1958	N.F.
SCANDARELLO	12/03/1950	6,7	5	0,111	8	4,8	1927	N.F.
PIAGANINI	06/04/2009	30,5	6,3	0,089	6	4,7	1955	N.F.
PROVVIDENZA	06/04/2009	20,3	6,3	0,132	5,5	7	1947	N.F.
RIO FUCINO	06/04/2009	23,1	6,3	0,117	5,5	6,1	1971	N.F.
SELLA PEDICATE	06/04/2009	20,1	6,3	0,134	5,5	7	1971	N.F.
POGGIO CANCELLI	06/04/2009	24,7	6,3	0,11	5,5	7,8	1969	N.F.
PIANA DEGLI ALBANESI	15/01/1968	outside selection criteria			7			S.L.V.
PIANA DEGLI ALBANESI	06/09/2002	16,1	5,6	0,093	7	5,8	1923	N.F.
MASSERIA NICODEMO	09/09/1998	4,7	5,4	0,182	6	12,2	1975	N.F.
COLLEMEZZO	14/10/1966	7,2	4,5	0,072	6,5	3,8	1928	N.A.
CORFINO	07/09/1920	8,8	6,48	0,319	10,0	18,8	1914	N.F.
CASTEL SAN VINCENZO	07/05/1984	1,5	5,67	0,312	8,0	25,8	1958	N.F.
CROSIIS	06/05/1976	8,5	6,43	0,312	9,5	17,1	1901	S.L.O.
VASCA OGLIASTRO	13/12/1990	2,2	5,41	0,241	6,5	3,9	1970	S.L.D.
MUROLUCANO	23/11/1980	19,3	6,89	0,227	8,0	20,3	1917	N.F.
VILLA PERA	26/11/1972	1,1	5,23	0,220	7,5	12,4	1955	N.F.
MULINELLO	13/12/1990	3,7	5,41	0,211	6,5	11,6	1970	S.L.O.
ACCIANO	26/09/1997	8,9	5,95	0,202	8,5	10,5	1986	S.L.D.
CROSIIS	15/09/1976	8,5	5,91	0,202	9,5	17,1	1901	S.L.O.
MONTAGNA SPACCATA 3	07/05/1984	7	5,67	0,190	8,0	13,1	1958	S.L.O.
FIUMARA GRANDE	13/12/1990	5	5,41	0,187	6,5	9,8	1970	N.F.
MONTAGNA SPACCATA 1	07/05/1984	7,3	5,67	0,185	8,0	9,3	1958	S.L.O.
MONTAGNA SPACCATA 2	07/05/1984	7,5	5,67	0,181	8,0	9,1	1958	S.L.O.
AMBIESTA	06/05/1976	18,6	6,43	0,160	8,5	8,5	1959	S.L.O.
GROTTACAMPANARO	07/05/1984	13,2	5,67	0,116	7,0	6,1	1954	N.F.
CA'SELVA	06/05/1976	28,3	6,43	0,107	9,0	5,5	1963	N.A.
CA'ZUL	06/05/1976	5,2	6,4	0,090	8,0	5,0		S.L.O.

Ogliastro

Ogliastro

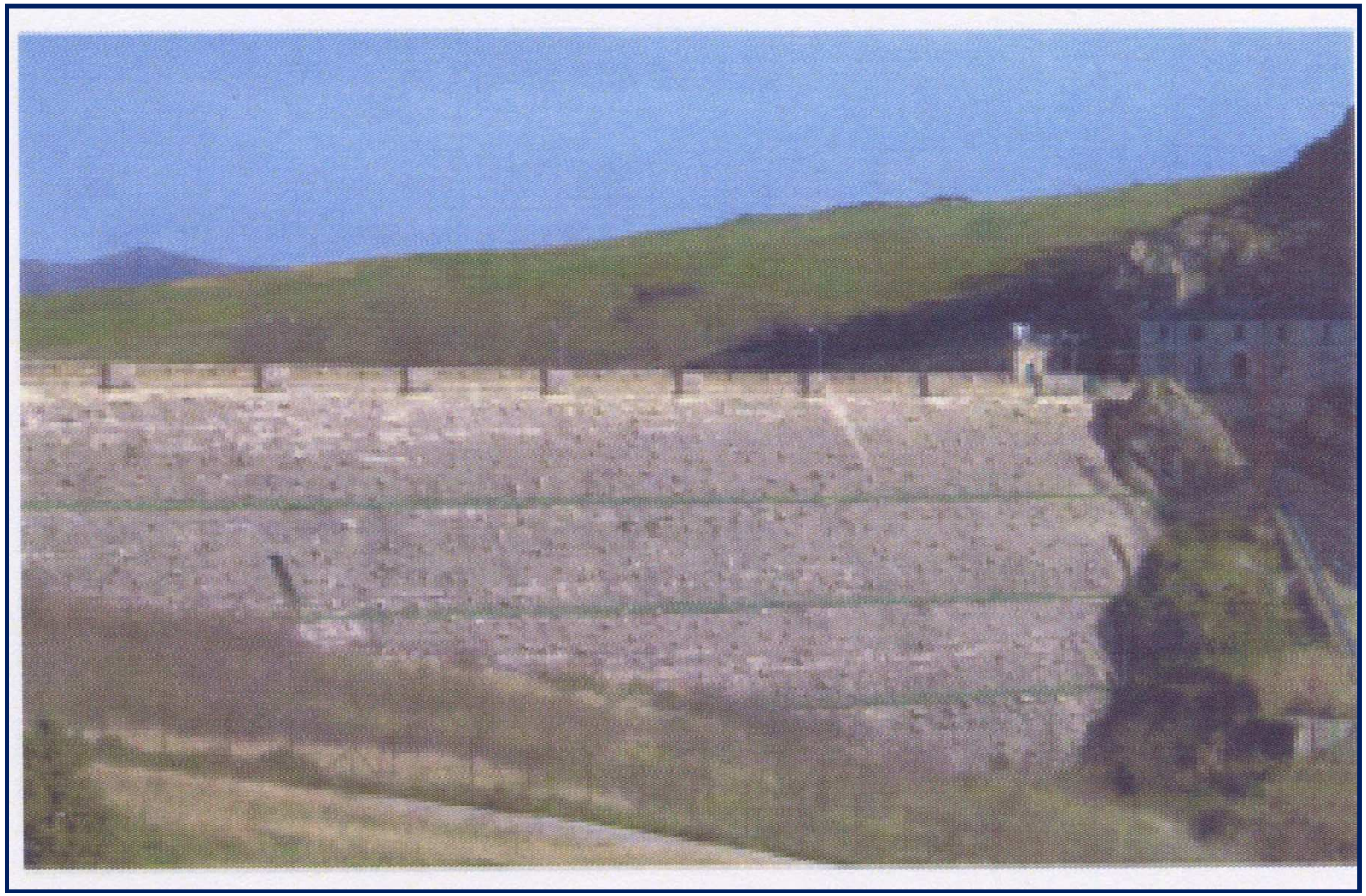
Ogliastro basin

H= 22 m

Volume L. 584/94 = 4,31 x 10^6 m^3
There were lesions in the bituminous lining

SEISMIC EVENT 13/12/1990
Imcs =6,5
M=5,41
D=2,2 Km
PGA=0,241g

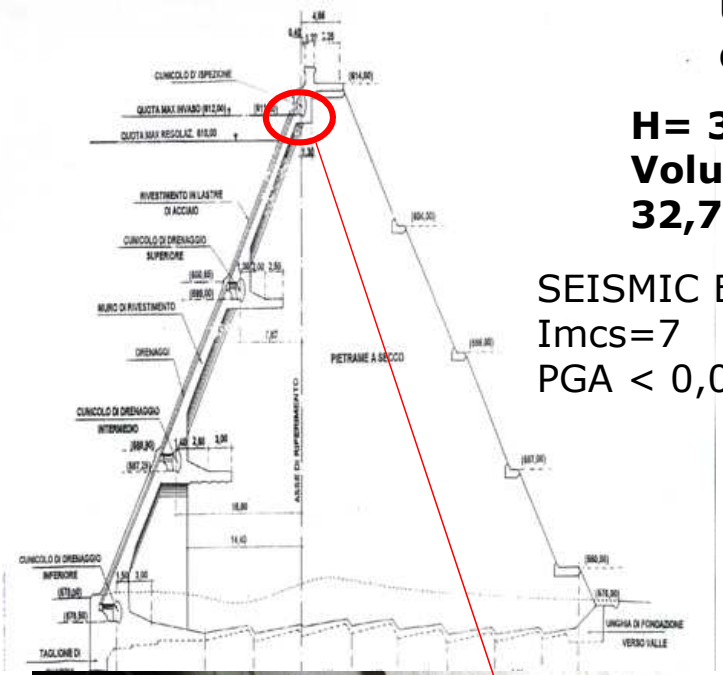
Piana degli Albanesi



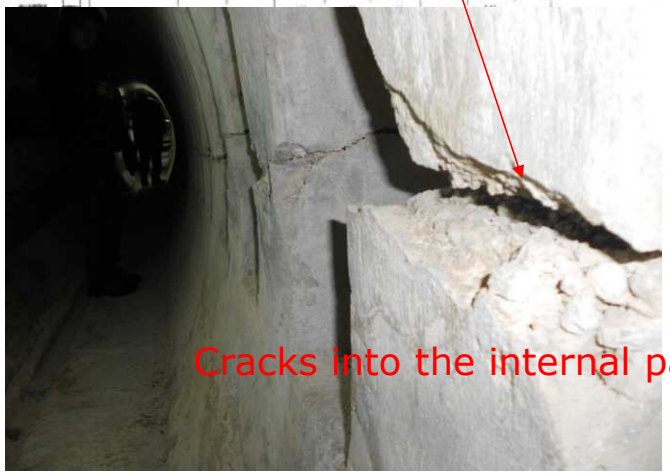
Piana degli Albanesi

Cracks in the internal passages with an uncontrolled release of water without compromising the stability of dam.

H= 38 m
Volume =
32,75 x10⁶ m³



SEISMIC EVENT 15/01/1968 BELICE
Imcs=7
PGA < 0,07 OUTSIDE SELECTION CRITERIA



Cracks into the internal passage

CONCLUSIONS

- The study shows that the dams generally have a good behavior under seismic events;
- Controls allow a level of maintenance and safety that can be considered satisfactory;
- Monitoring activities reduce risk of critical behaviour during a strong earthquake;
- The activities of the group have been presented at the 9th ICOLD European Club Symposium, Venice 10-12 April 2013,: "Observed behavior of Italian dams under historical earthquakes" A. Catalano, R. Caruana, F. Del Gizzi, A. De Sortis

ITCOLD Working Group
'Behaviour of Italian dams for historical earthquakes'

EWG Dams and Earthquakes

Strong motion data recorded during the 2016-2017 seismic sequence in Central Italy
Preliminary remarks

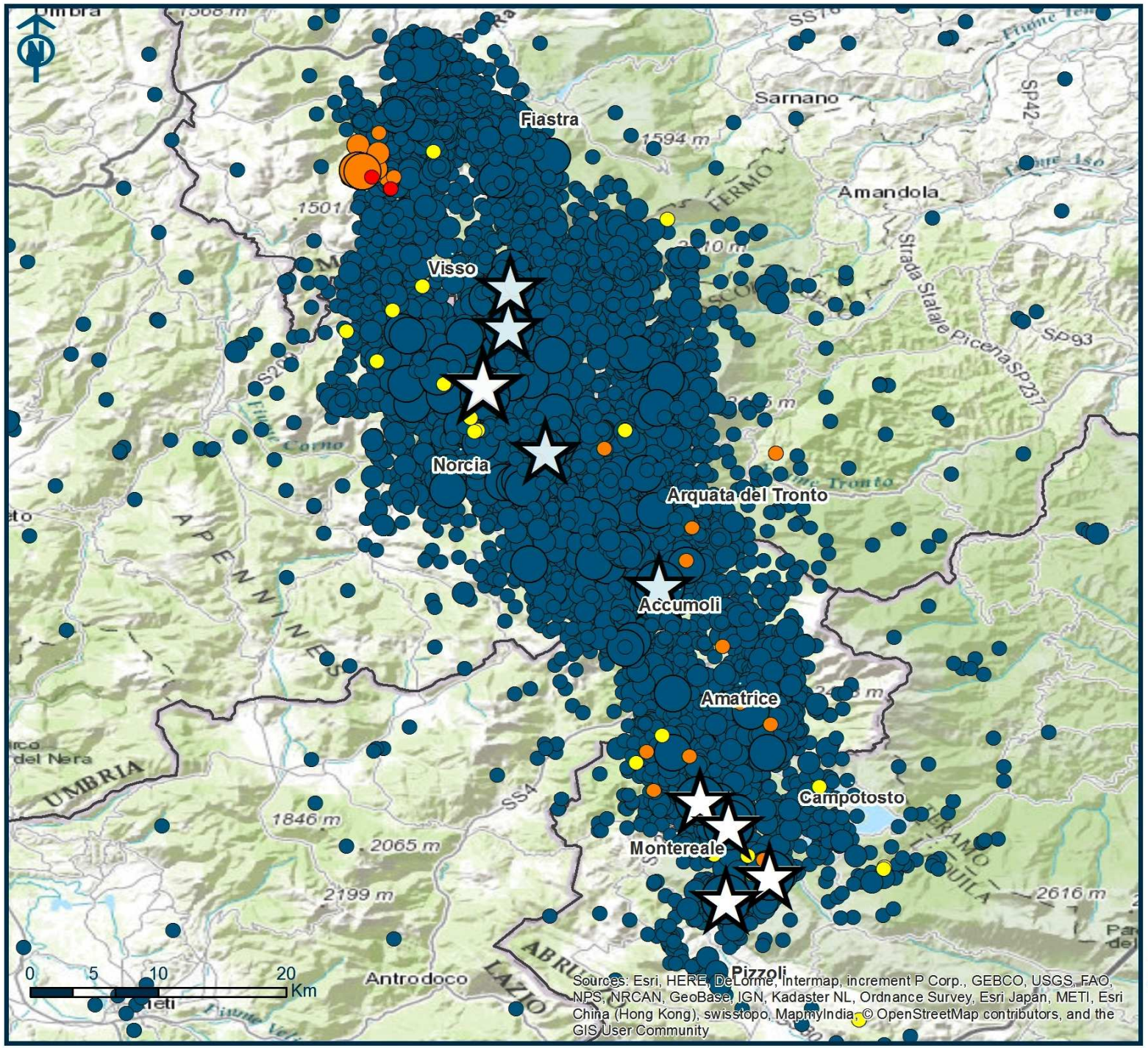
Adriano De Sortis

Roma 6,7 Febbraio 2017

Summary

- Locations of the main shocks and main seismic sources
- Large dams in epicentral area
- Large dams and seismic sources
- Strong motion data recorded near large dams
- Post-earthquake experimental modal analysis

Seismic sequence in Central



INGVterremoti

SEQUENZA SISMICA IN ITALIA CENTRALE (agg. 3 febbraio ore 08:00)

Magnitudo (M)

- da 2.0 a 2.9
- da 3.0 a 3.9
- da 4.0 a 4.9
- da 5.0

Tempo

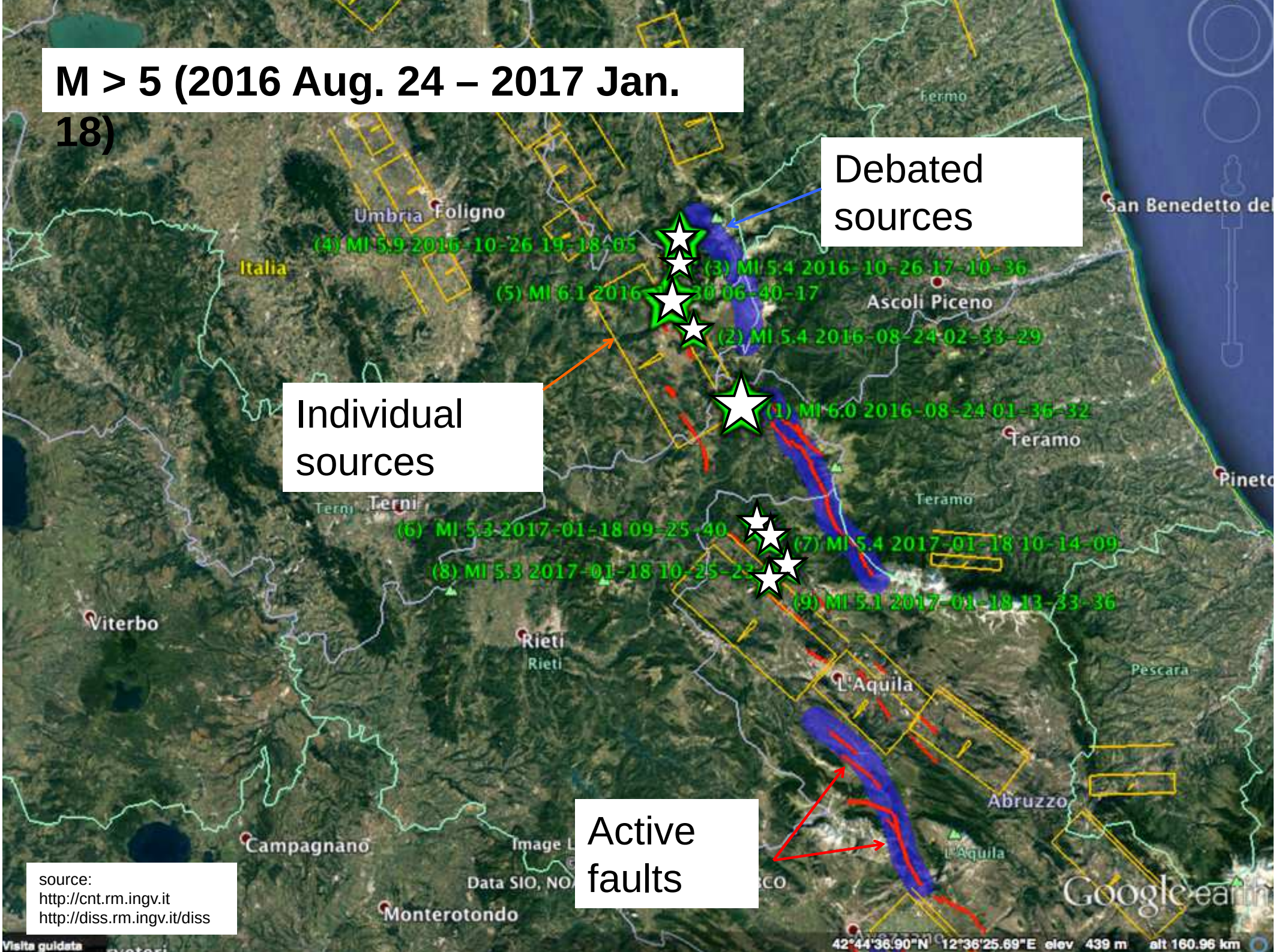
- Ultima ora
- Ultime 24 ore
- Ultime 72 ore
- Dal 24 agosto 2016

fonte dati: http://cnt.rm.ingv.it

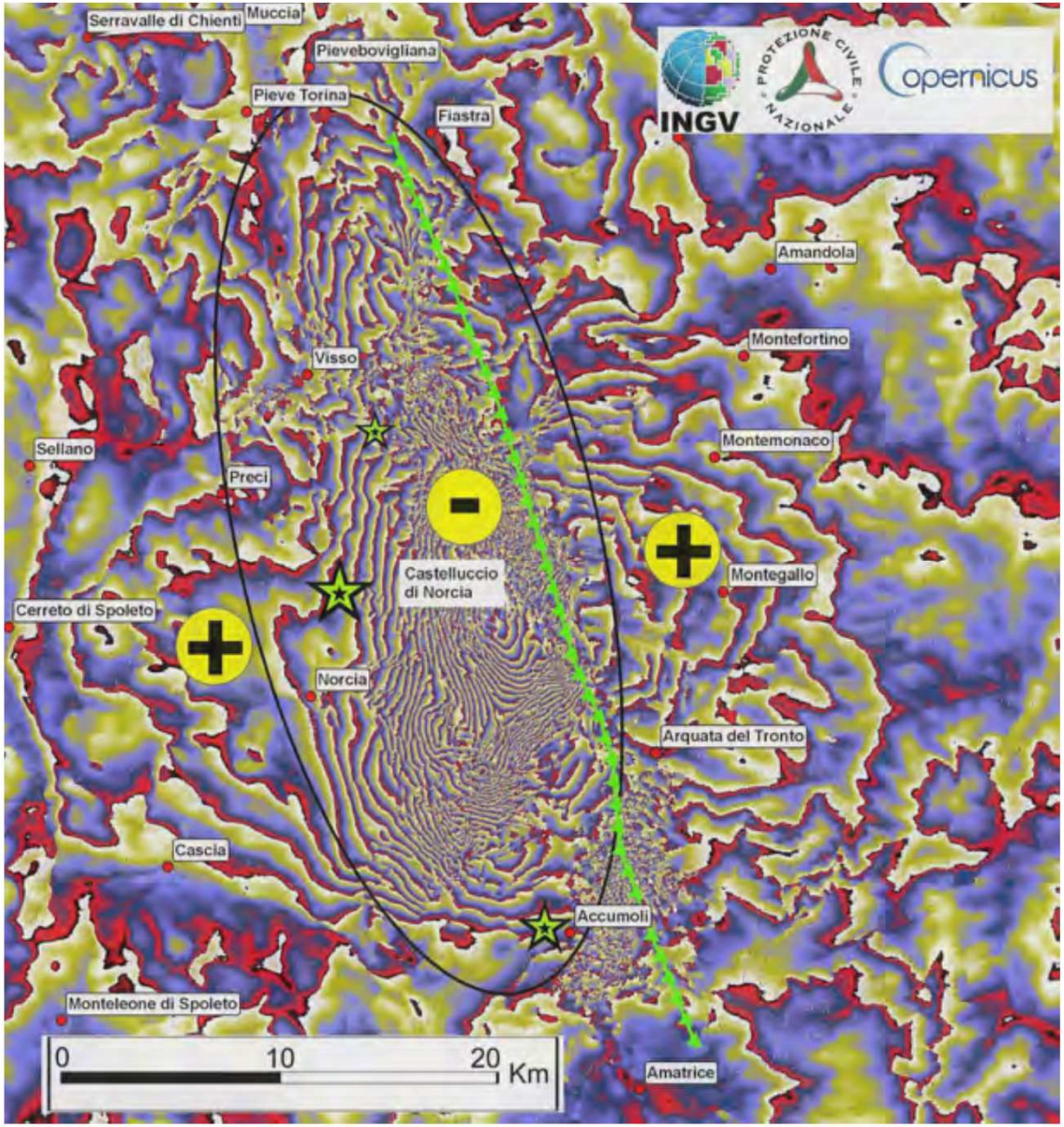
SEGUICI SU:
http://ingvterremoti.wordpress.com

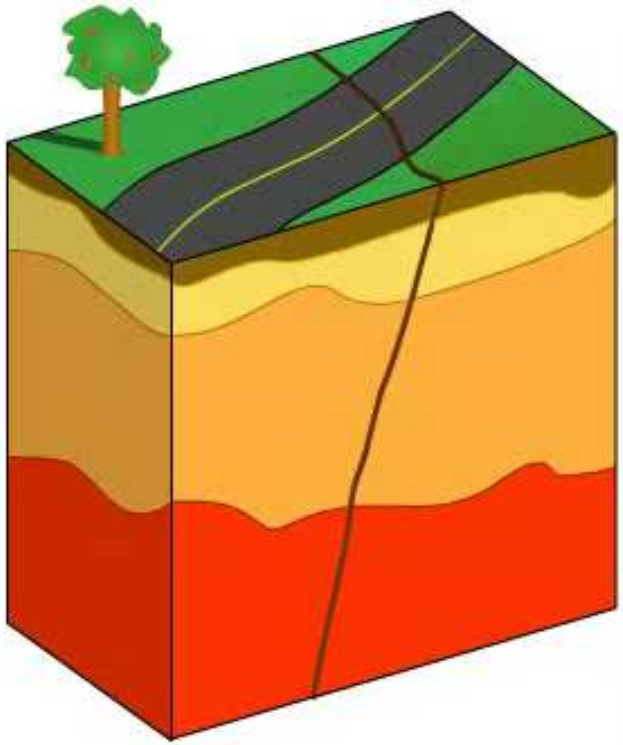
Events with Magnitude ≥ 5

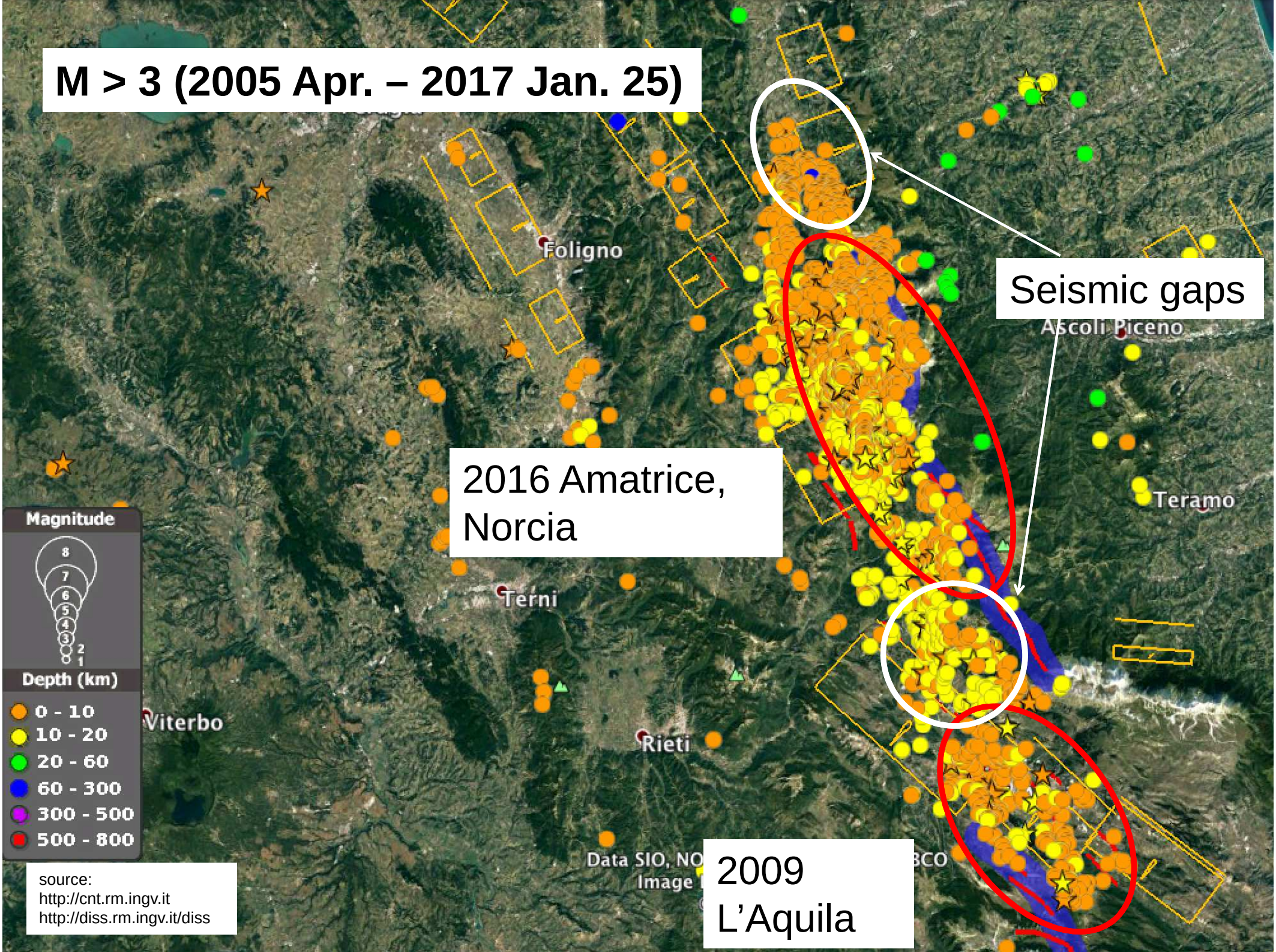
Date	Time (UTC)	Lat.	Long.	Depth (Km)	Magnitude	Strike (°)
24/08/16	2.33.29	42.792	13.151	8	5.4	135
24/08/16	1.36.32	42.698	13.234	8.1	6	155
26/10/16	19.18.06	42.909	13.129	7.5	5.9	159
26/10/16	17.10.36	42.88	13.128	8.7	5.4	161
30/10/16	6.40.17	42.832	13.111	9.2	6.5	151
18/01/17	13.33.37	42.477	13.281	10	5	188
18/01/17	10.25.24	42.494	13.311	8.9	5.4	140
18/01/17	10.14.10	42.529	13.282	9.1	5.5	161
18/01/17	9.25.40	42.547	13.262	9.2	5.1	153

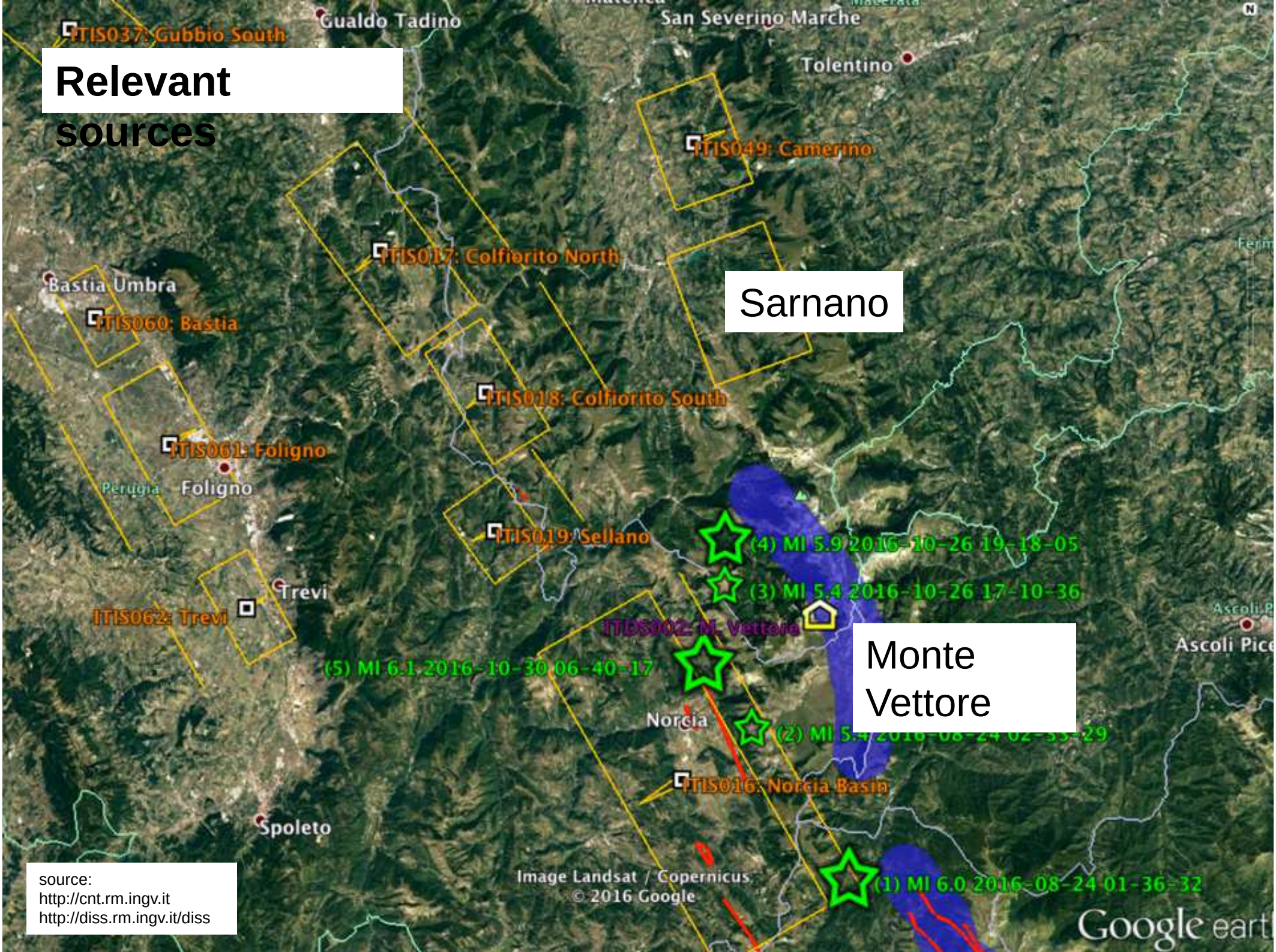

M > 5 (2016 Aug. 24 – 2017 Jan. 18)
Debated sources
Individual sources
Active faults
source:
http://cnt.rm.ingv.it
http://diss.rm.ingv.it/diss
Umbria
Foligno
Italia
(4) Ml 5.9 2016-10-26 19-18-05
(3) Ml 5.4 2016-10-26 17-10-36
(5) Ml 6.1 2016-10-30 06-40-17
(2) Ml 5.4 2016-08-24 02-33-29
(1) Ml 6.0 2016-08-24 01-36-32
Ascoli Piceno
Teramo
Terni
(6) Ml 5.3 2017-01-18 09-25-40
(7) Ml 5.4 2017-01-18 10-14-09
(8) Ml 5.3 2017-01-18 10-25-23
(9) Ml 5.1 2017-01-18 13-33-36
Viterbo
Rieti
L'Aquila
Abruzzo
Pescara
Campagnano
Monterotondo
Fermo
San Benedetto del
Pineto
Google earth

Aerial vertical displacement measured using interferometric satellite radar (26/10, 30/10)

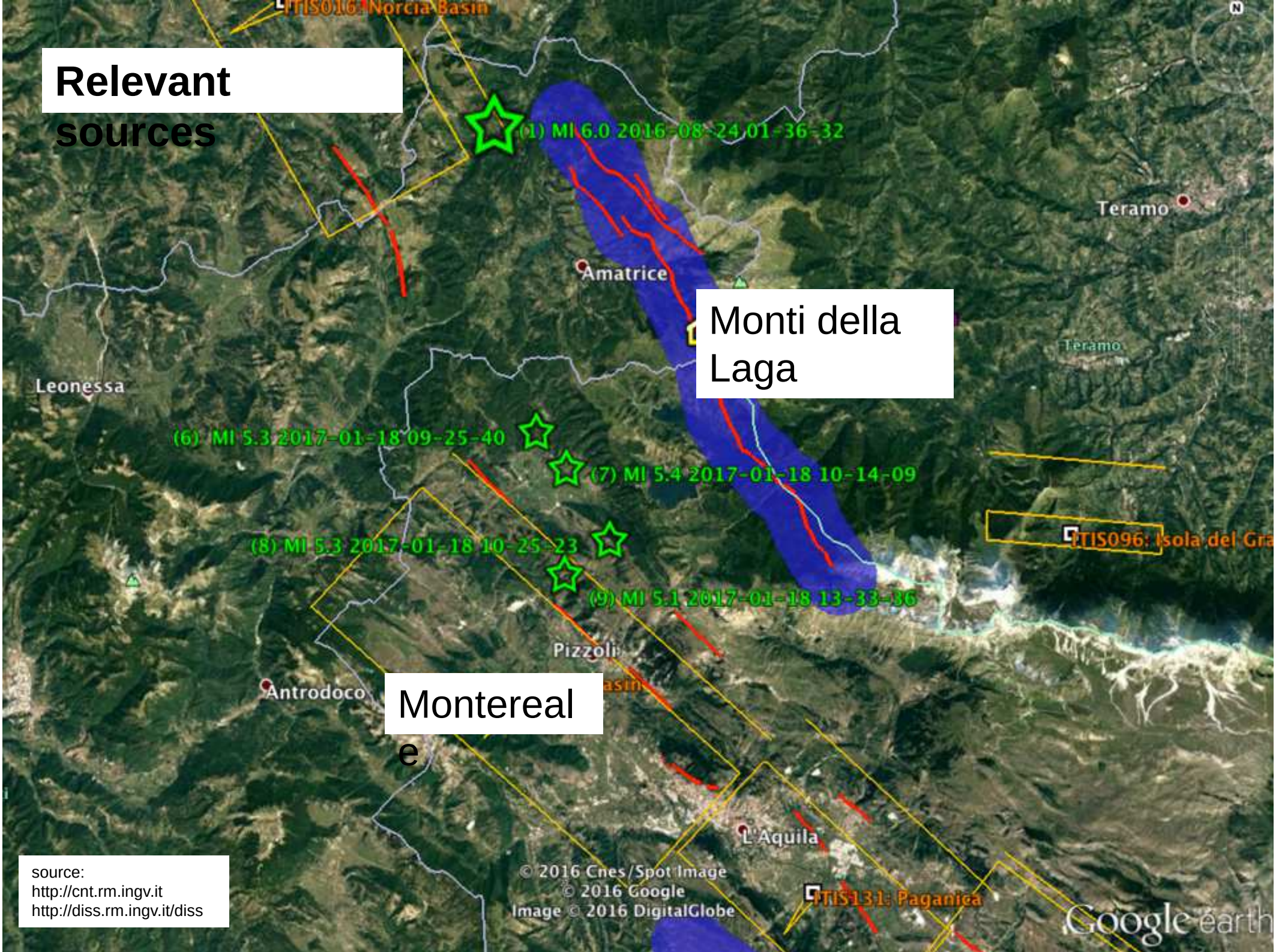




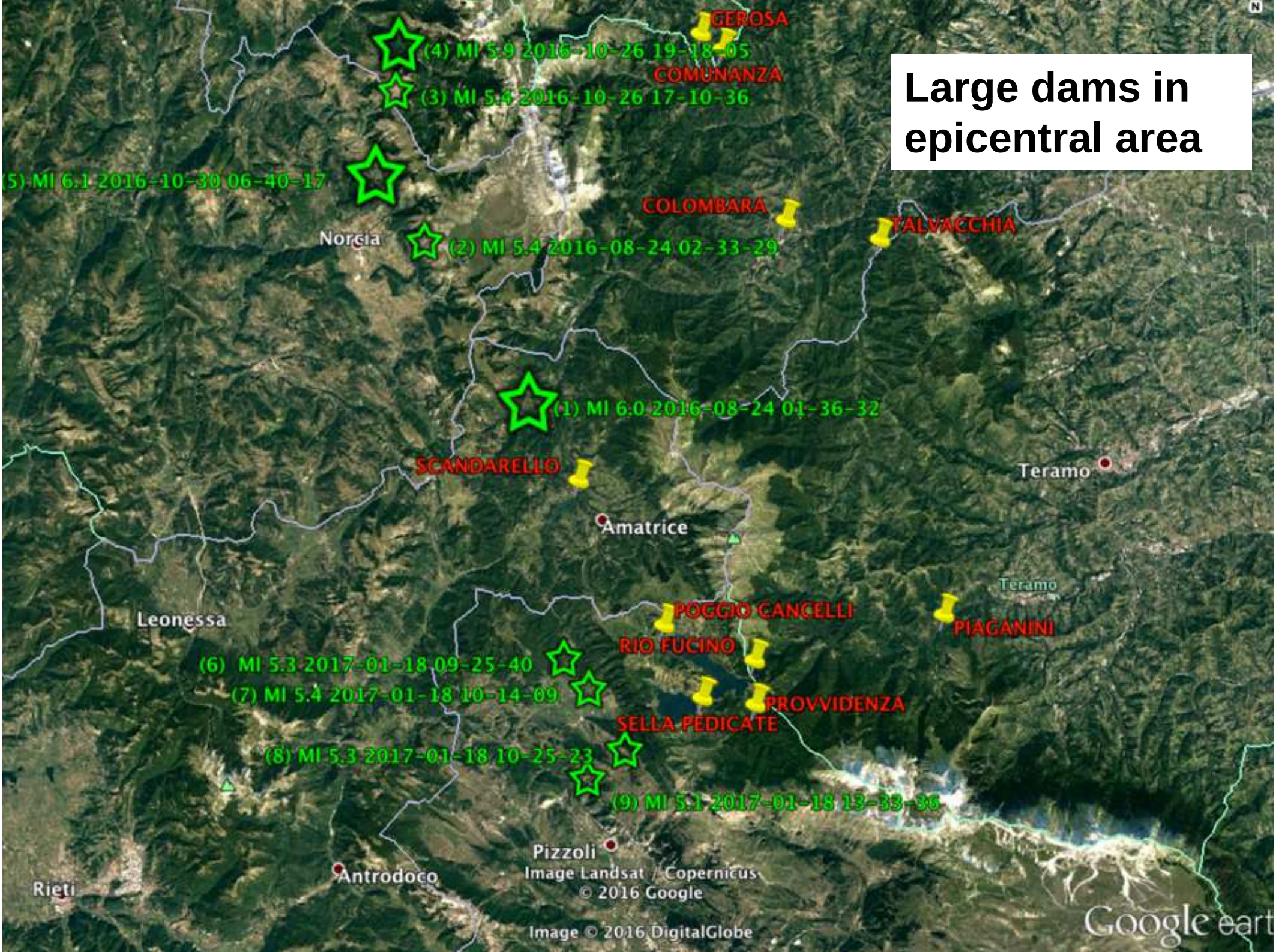

M > 3 (2005 Apr. – 2017 Jan. 25)
Seismic gaps
2016 Amatrice, Norcia
2009 L'Aquila
Foligno
Ascoli Piceno
Teramo
Terni
Viterbo
Rieti
Magnitude
8
7
6
5
4
3
2
1
Depth (km)
0 - 10
10 - 20
20 - 60
60 - 300
300 - 500
500 - 800
source:
http://cnt.rm.ingv.it
http://diss.rm.ingv.it/diss

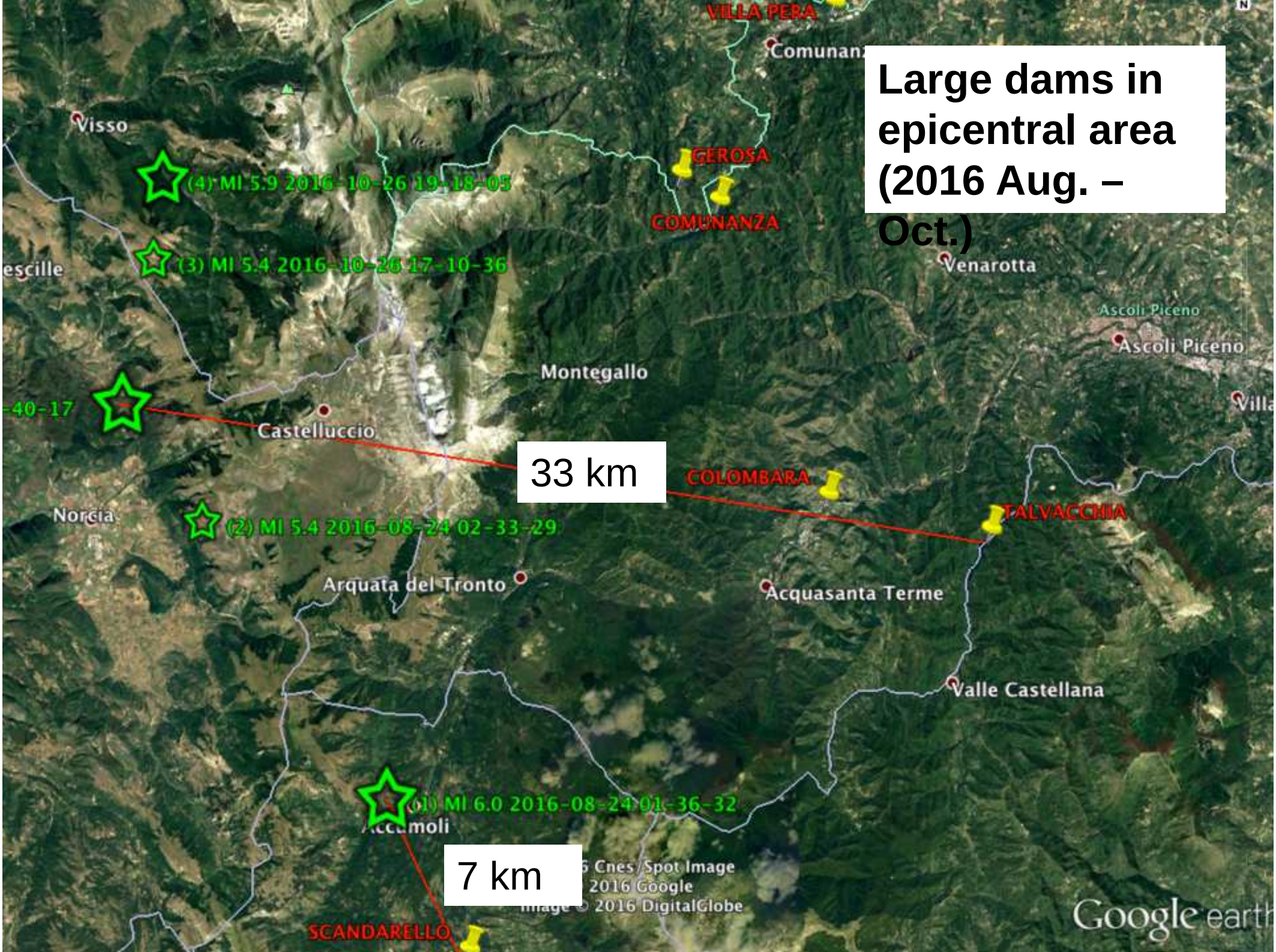


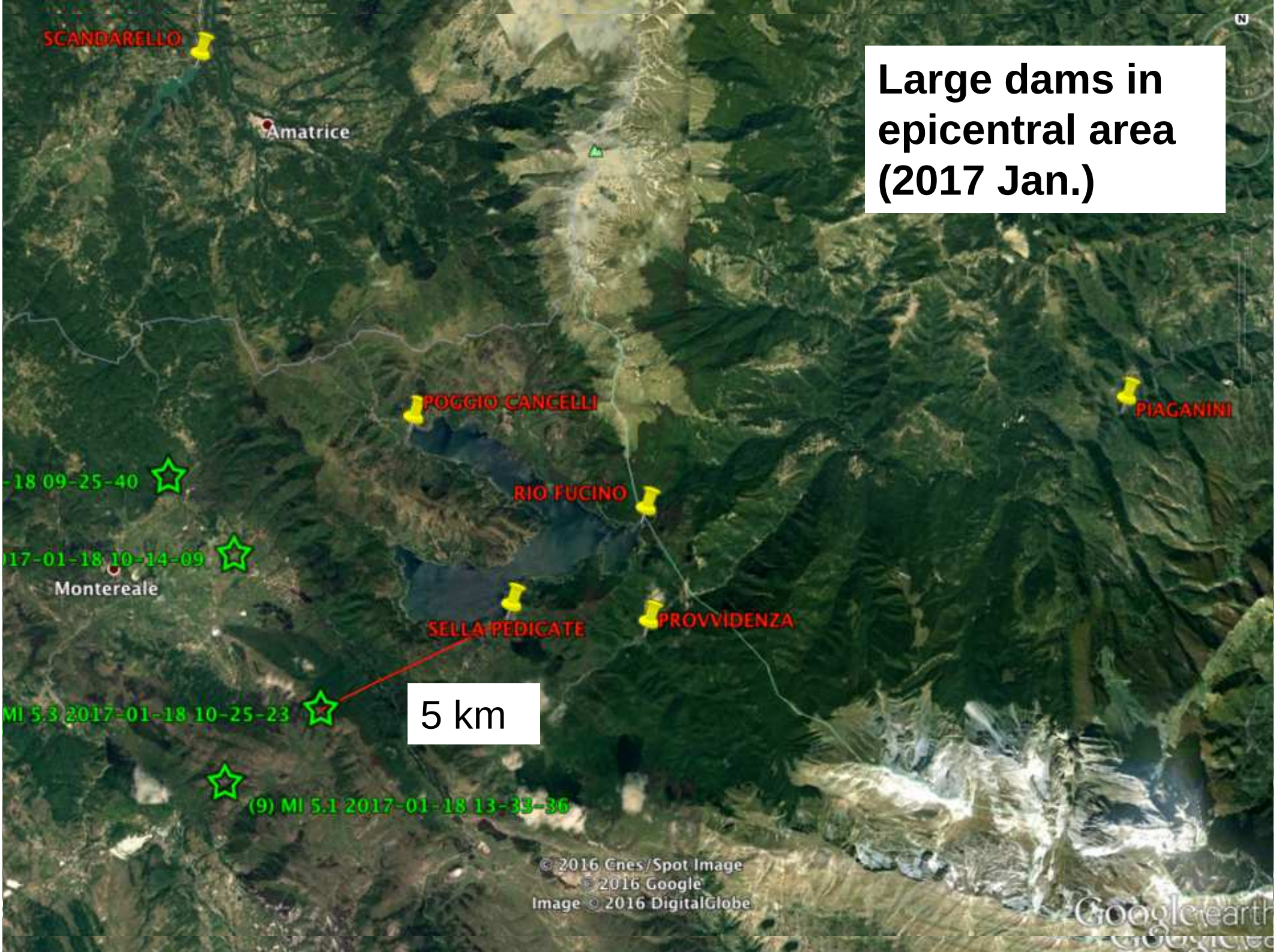
source:
http://cnt.rm.ingv.it
http://diss.rm.ingv.it/diss

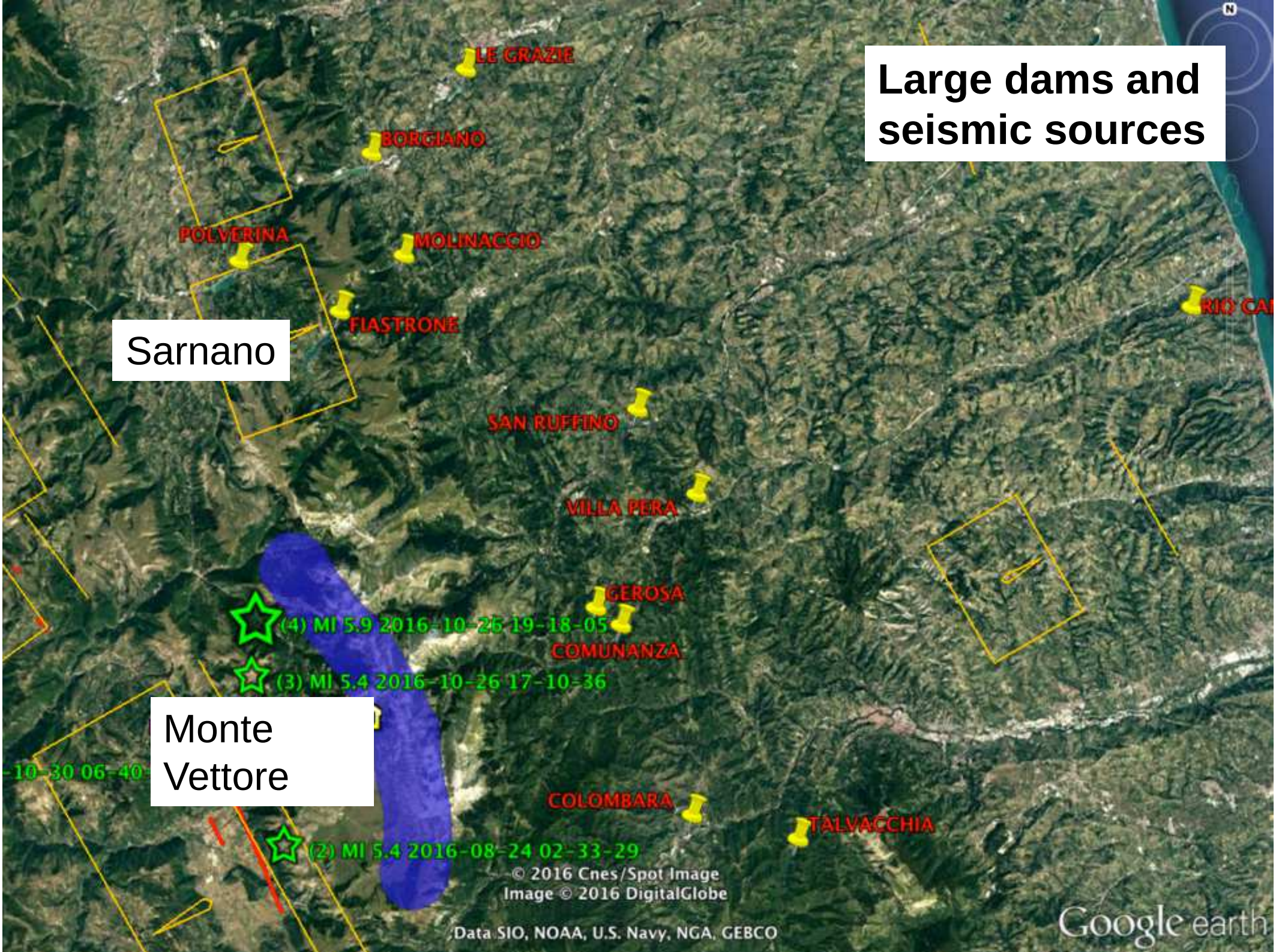


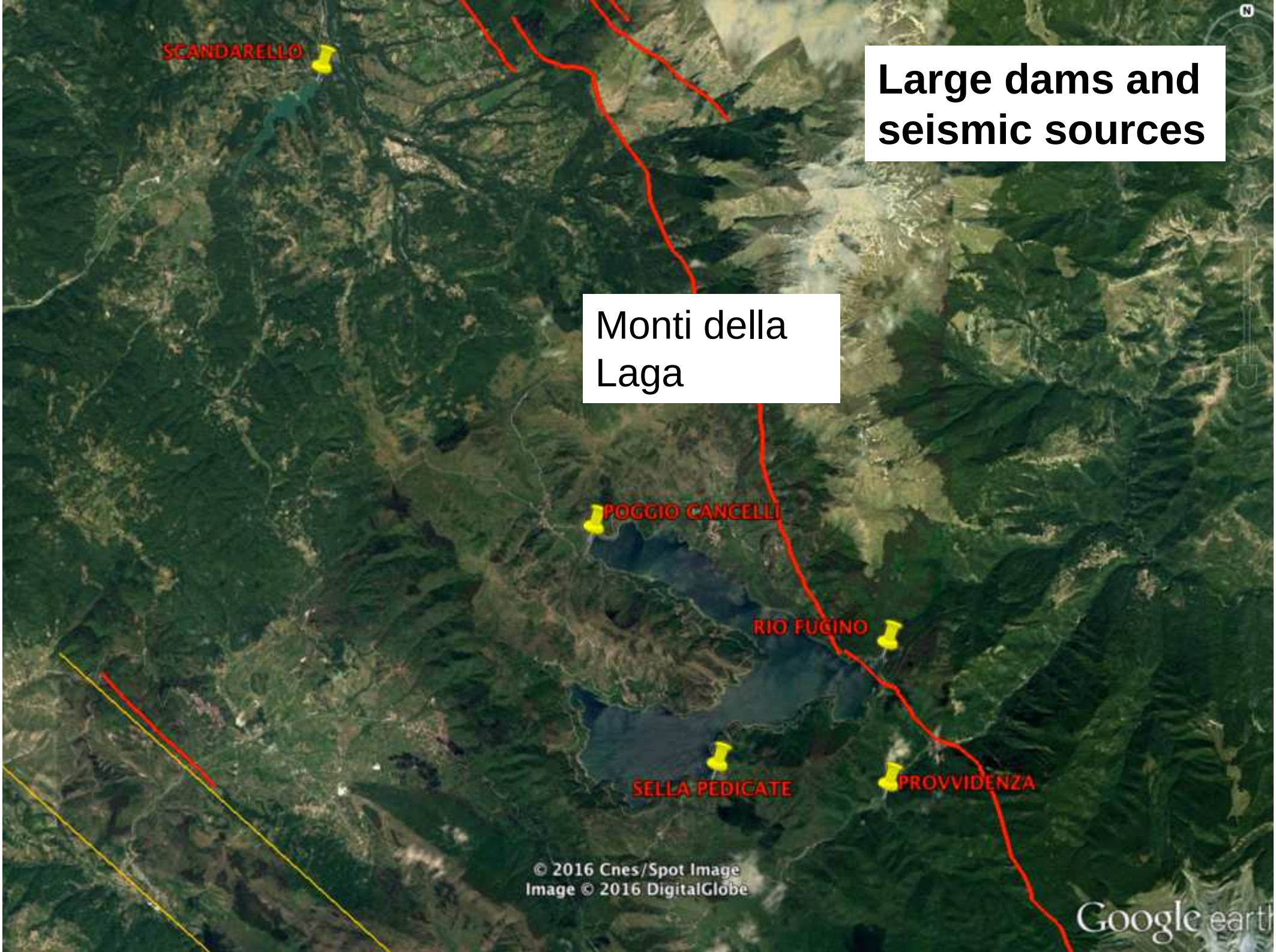
source:
http://cnt.rm.ingv.it
http://diss.rm.ingv.it/diss

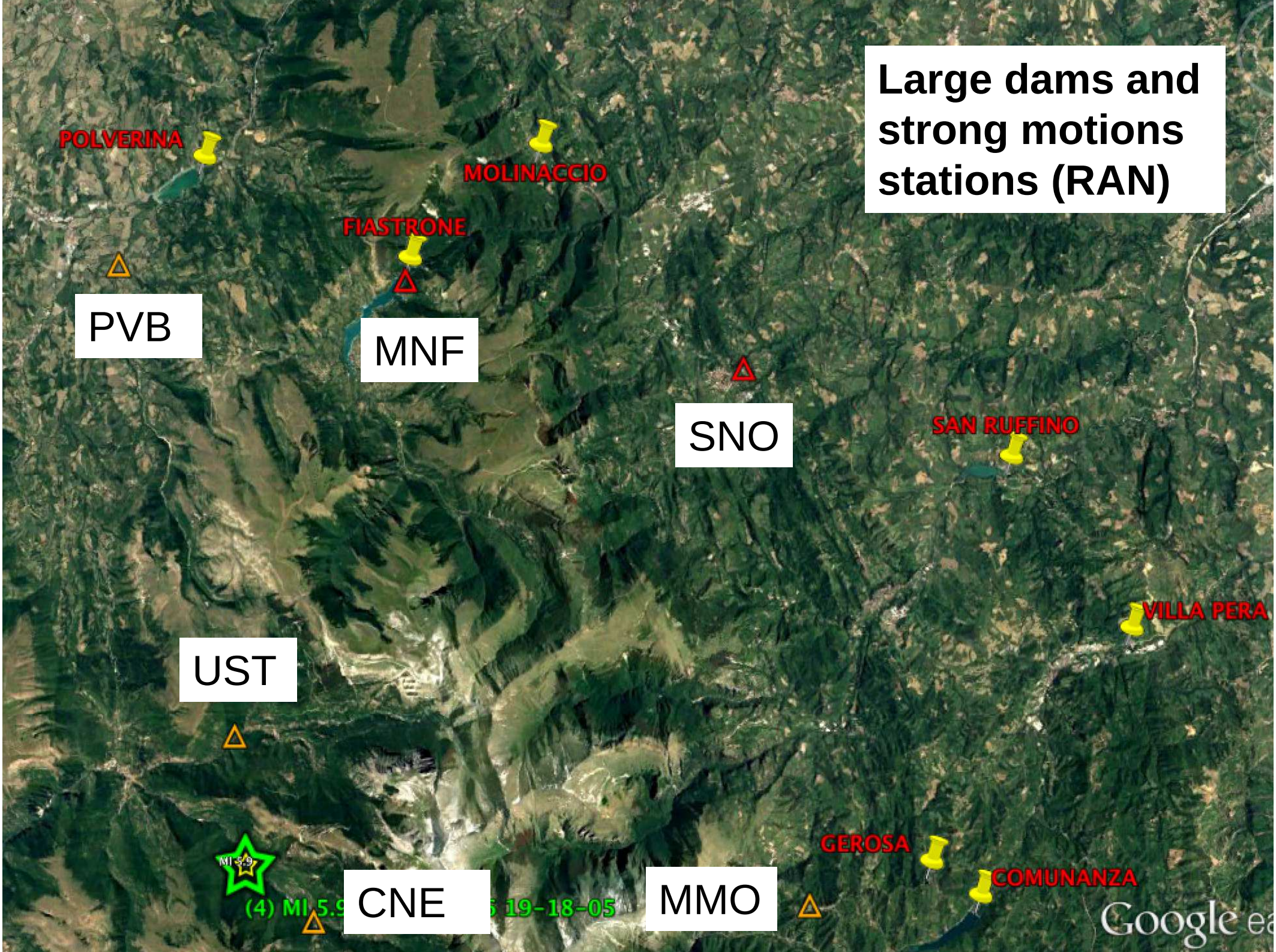

Large dams in epicentral area
GEROSA
(4) MI 5.9 2016-10-26 19-18-05
COMUNANZA
(3) MI 5.4 2016-10-26 17-10-36
(5) MI 6.1 2016-10-30 06-40-17
COLOMBARA
TALVACCHIA
Norcia
(2) MI 5.4 2016-08-24 02-33-29
(1) MI 6.0 2016-08-24 01-36-32
SCANDARELLO
Teramo
Amatrice
Teramo
POGGIO CANCELLI
PIAGANINI
Leonessa
RIO FUCINO
(6) MI 5.3 2017-01-18 09-25-40
(7) MI 5.4 2017-01-18 10-14-09
PROVVIDENZA
SELLA PEDICATE
(8) MI 5.3 2017-01-18 10-25-23
(9) MI 5.1 2017-01-18 13-33-36
Pizzoli
Antrodoco
Rieti
Image Landsat / Copernicus
© 2016 Google
Image © 2016 DigitalGlobe
Google earth

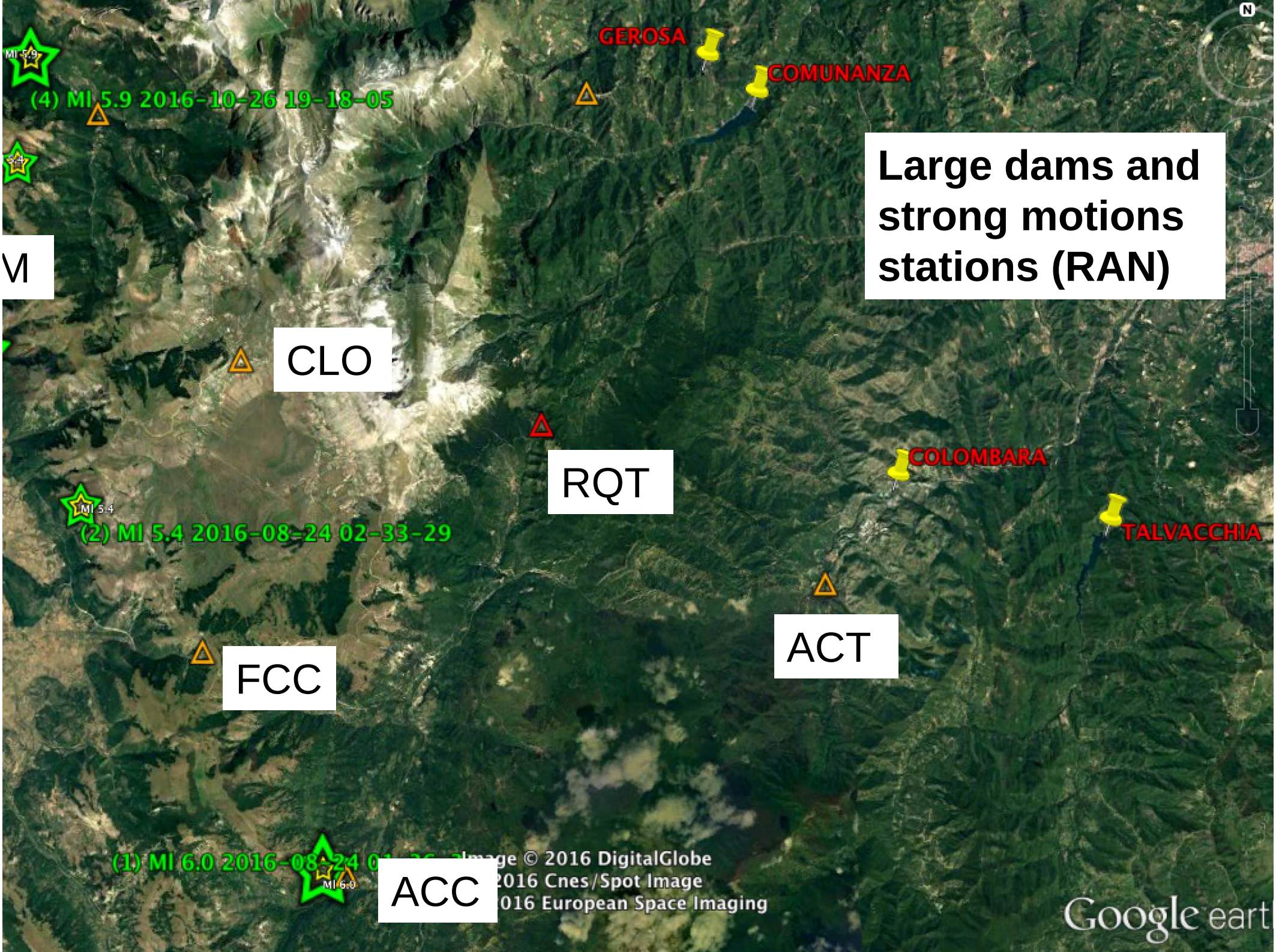

Large dams in epicentral area (2016 Aug. – Oct.)
VILLA PERA
Comunanza
Visso
GEROSA
COMUNANZA
(4) Ml 5.9 2016-10-26 19-18-05
(3) Ml 5.4 2016-10-26 17-10-36
Venarotta
Ascoli Piceno
Ascoli Piceno
Montegallo
Castelluccio
33 km
COLOMBARA
TALVACCHIA
Norcia
(2) Ml 5.4 2016-08-24 02-33-29
Arquata del Tronto
Acquasanta Terme
Valle Castellana
(1) Ml 6.0 2016-08-24 01-36-32
7 km
SCANDARELLO
Cnes / Spot Image
2016 Google
Image © 2016 DigitalGlobe
Google earth

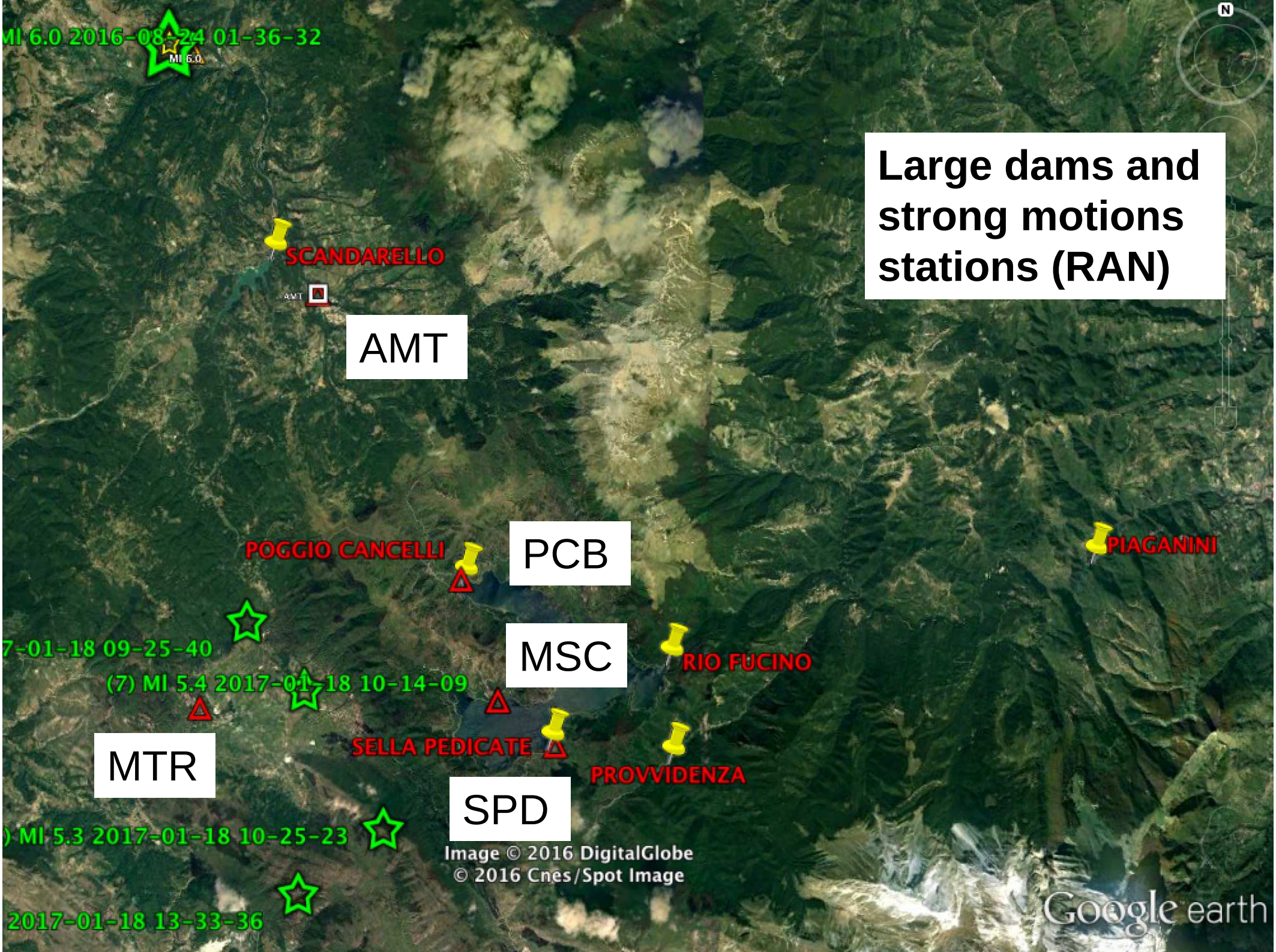

Large dams in epicentral area (2017 Jan.)
SCANDARELLO
Amatrice
POGGIO CANCELLI
PIAGANINI
RIO FUCINO
-18 09-25-40
017-01-18 10-14-09
Montereale
SELLA PEDICATE
PROVVIDENZA
MI 5.3 2017-01-18 10-25-23
5 km
(9) MI 5.1 2017-01-18 13-33-36
© 2016 Cnes/Spot Image
© 2016 Google
Image © 2016 DigitalGlobe
Google earth

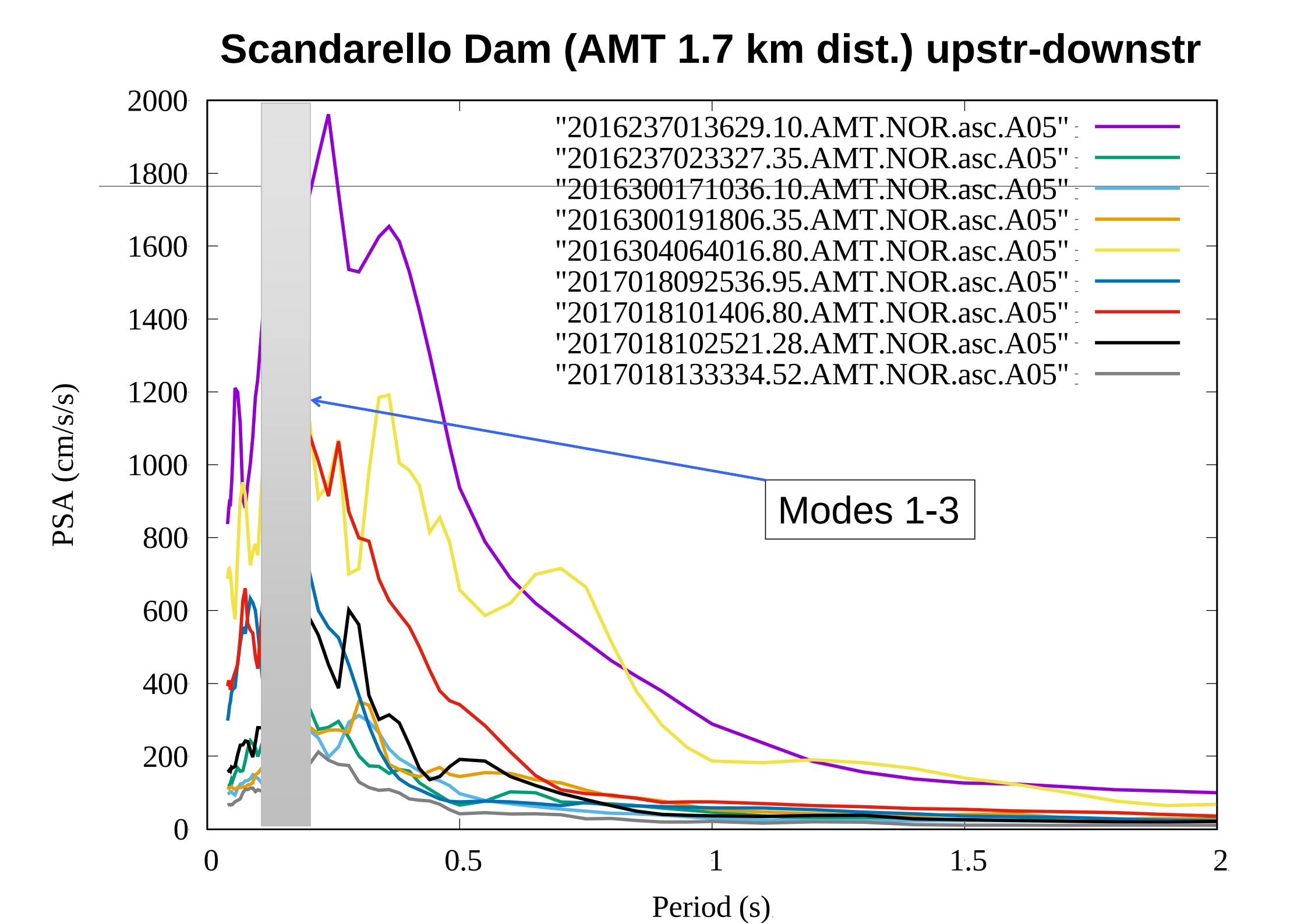

Large dams and seismic sources
LE GRAZIE
BORGIANO
POLVERINA
MOLINACCIO
FIASTRONE
Sarnano
SAN RUFFINO
VILLA PERA
GEROSA
COMUNANZA
(4) Ml 5.9 2016-10-26 19-18-05
(3) Ml 5.4 2016-10-26 17-10-36
Monte Vettore
COLOMBARA
TALVACCHIA
(2) Ml 5.4 2016-08-24 02-33-29
© 2016 Cnes/Spot Image
Image © 2016 DigitalGlobe
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google earth

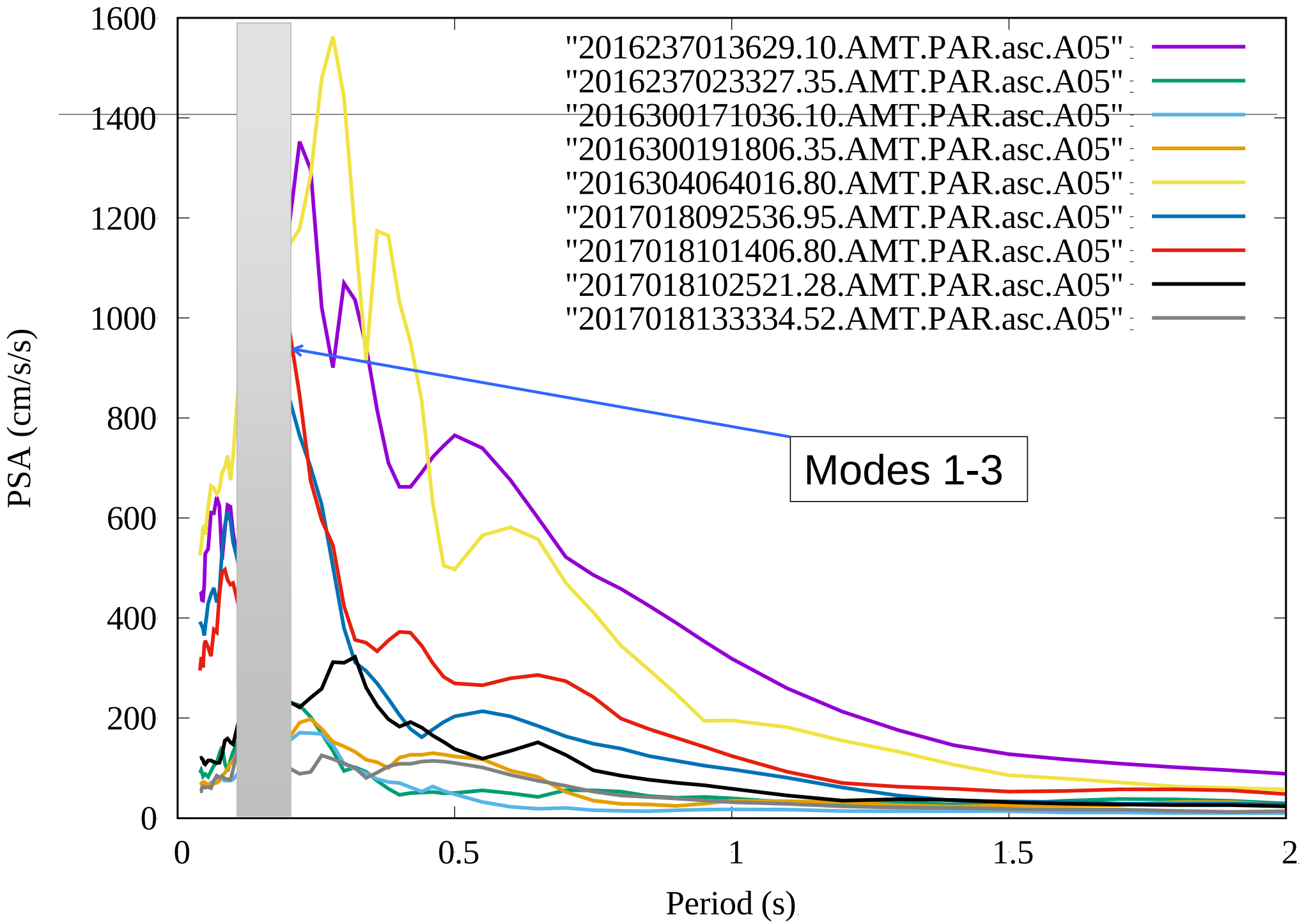

Large dams and seismic sources
Monti della Laga
SCANDARELLO
POGGIO CANCELLI
RIO FUCINO
SELLA PEDICATE
PROVVIDENZA
© 2016 Cnes/Spot Image
Image © 2016 DigitalGlobe
Google earth


Large dams and strong motions stations (RAN)
POLVERINA
MOLINACCIO
FIASTRONE
PVB
MNF
SNO
SAN RUFFINO
VILLA PERA
UST
GEROSA
COMUNANZA
CNE
MMO
Google

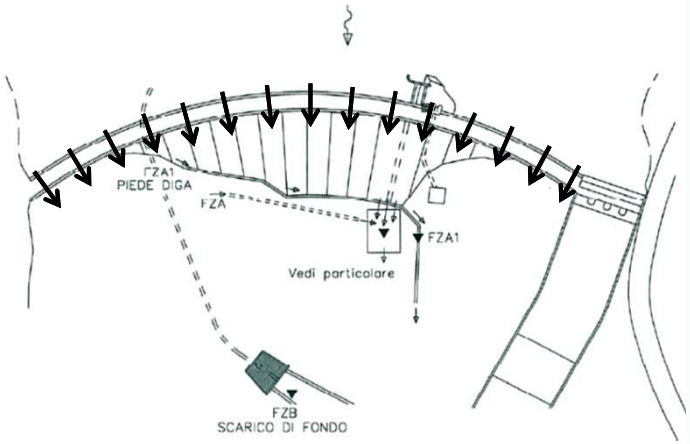

GEROSA
COMUNANZA
Large dams and strong motions stations (RAN)
(4) Ml 5.9 2016-10-26 19-18-05
CLO
RQT
COLOMBARA
TALVACCHIA
(2) Ml 5.4 2016-08-24 02-33-29
ACT
FCC
ACC
Image © 2016 DigitalGlobe
2016 Cnes/Spot Image
016 European Space Imaging
Google earth

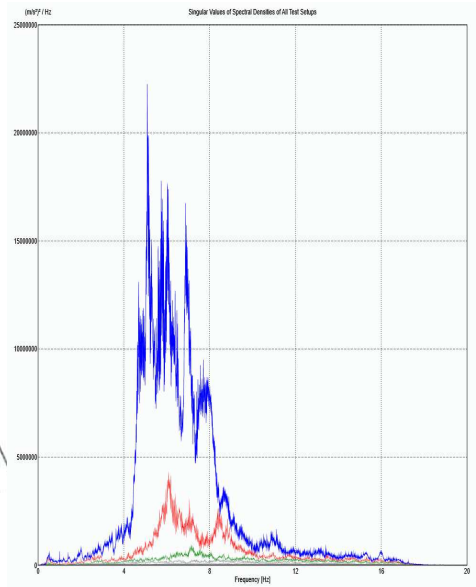

Ml 6.0 2016-08-24 01-36-32
Large dams and strong motions stations (RAN)
SCANDARELLO
AMT
AMT
POGGIO CANCELLI
PCB
PIAGANINI
7-01-18 09-25-40
MSC
RIO FUCINO
(7) Ml 5.4 2017-01-18 10-14-09
SELLA PEDICATE
PROVVIDENZA
MTR
SPD
) Ml 5.3 2017-01-18 10-25-23
Image © 2016 DigitalGlobe
© 2016 Cnes/Spot Image
2017-01-18 13-33-36
Google earth

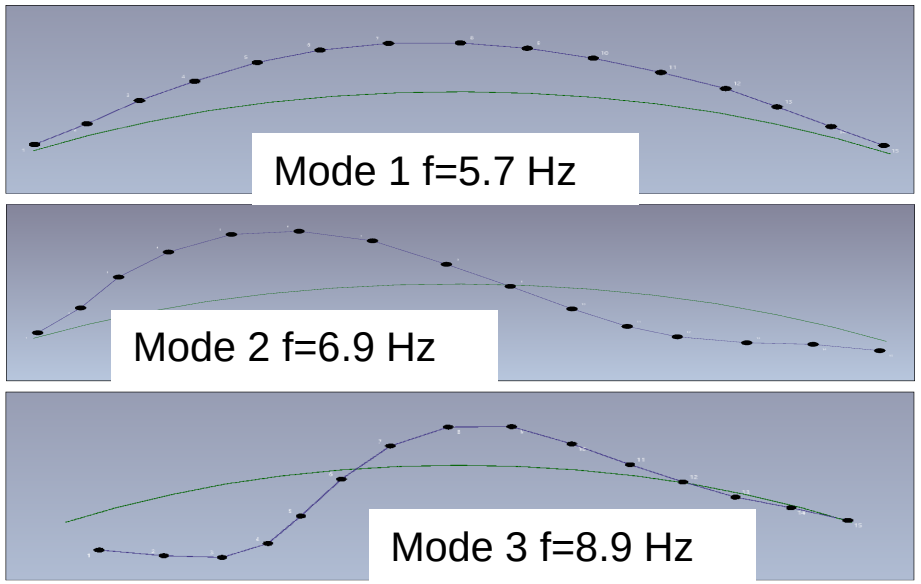

Scandarello Dam (AMT 1.7 km dist.) upstr-downstr
"2016237013629.10.AMT.NOR.asc.A05"
"2016237023327.35.AMT.NOR.asc.A05"
"2016300171036.10.AMT.NOR.asc.A05"
"2016300191806.35.AMT.NOR.asc.A05"
"2016304064016.80.AMT.NOR.asc.A05"
"2017018092536.95.AMT.NOR.asc.A05"
"2017018101406.80.AMT.NOR.asc.A05"
"2017018102521.28.AMT.NOR.asc.A05"
"2017018133334.52.AMT.NOR.asc.A05"
Modes 1-3
PSA (cm/s/s)
Period (s)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0
0.5
1
1.5
2

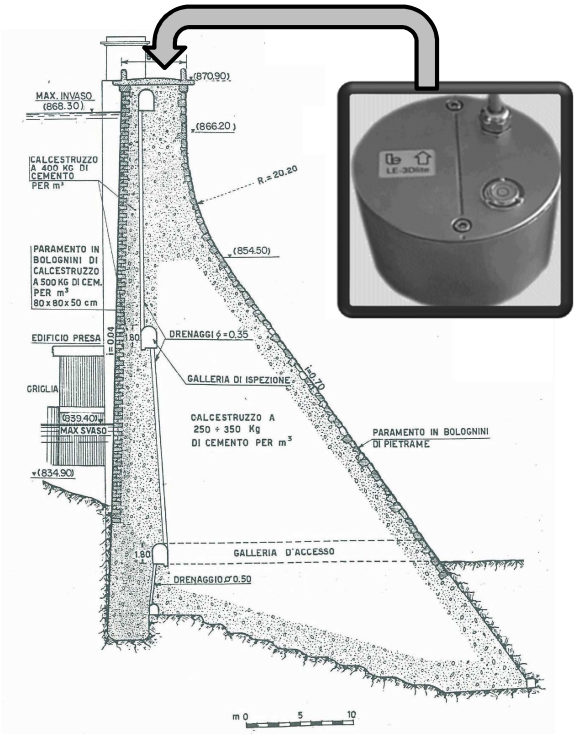

Scandarello Dam (AMT 1.7 km dist.) abut-abut
1600
1400
1200
1000
800
600
400
200
0
PSA (cm/s/s)
0
0.5
1
1.5
2
Period (s)
"2016237013629.10.AMT.PAR.asc.A05"
"2016237023327.35.AMT.PAR.asc.A05"
"2016300171036.10.AMT.PAR.asc.A05"
"2016300191806.35.AMT.PAR.asc.A05"
"2016304064016.80.AMT.PAR.asc.A05"
"2017018092536.95.AMT.PAR.asc.A05"
"2017018101406.80.AMT.PAR.asc.A05"
"2017018102521.28.AMT.PAR.asc.A05"
"2017018133334.52.AMT.PAR.asc.A05"
Modes 1-3

Post-earthquake experimental modal analysis Scandarello dam

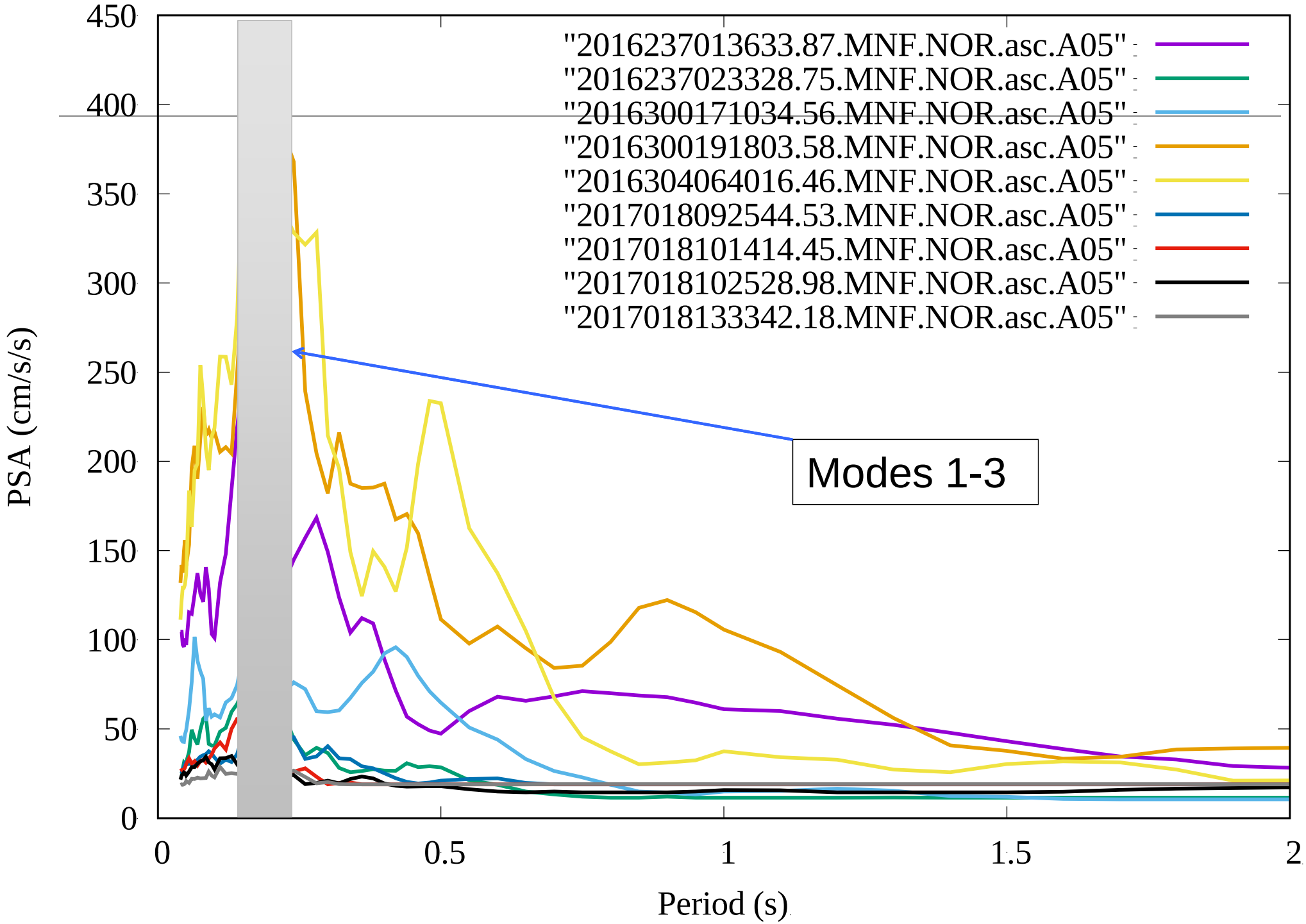


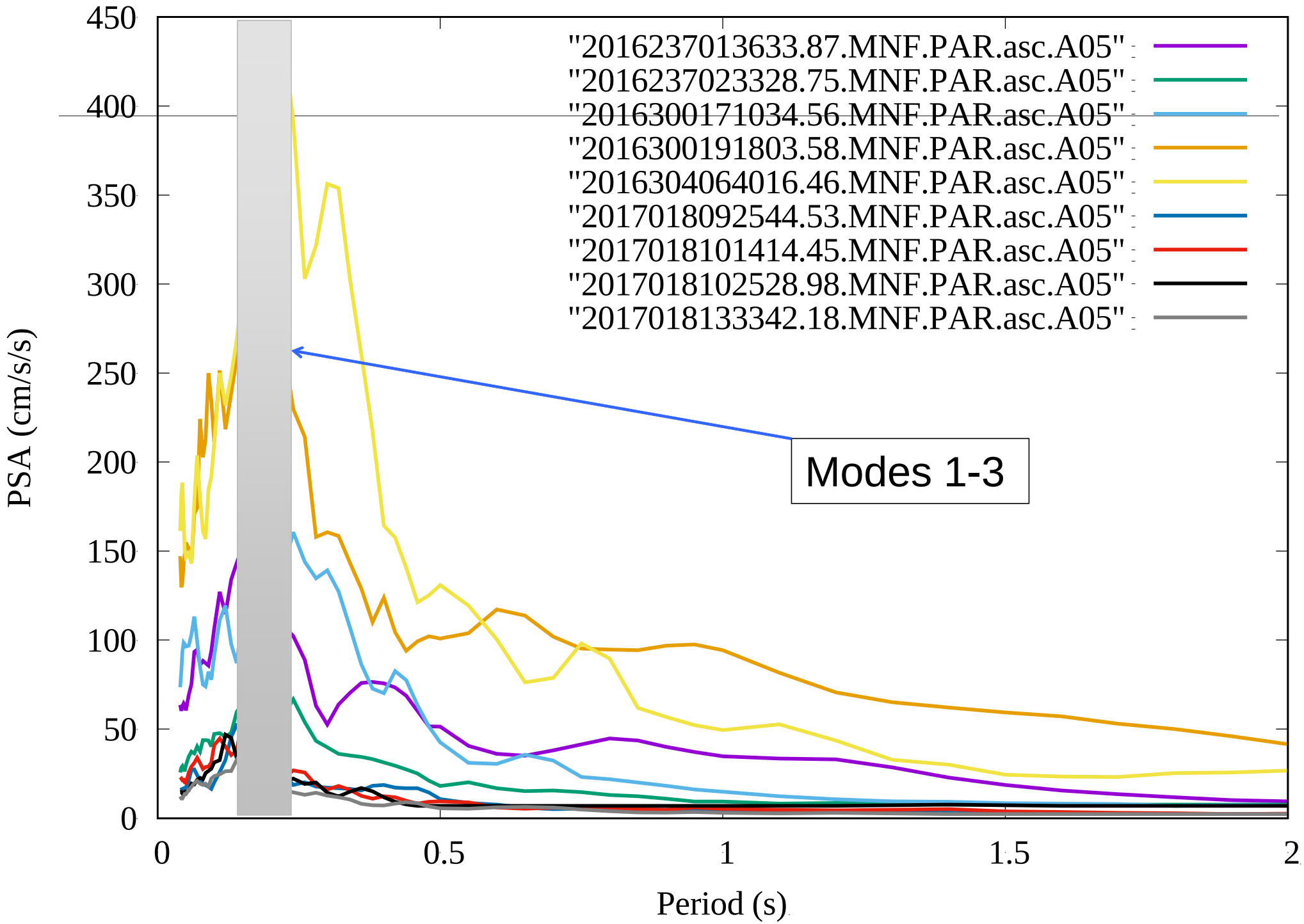


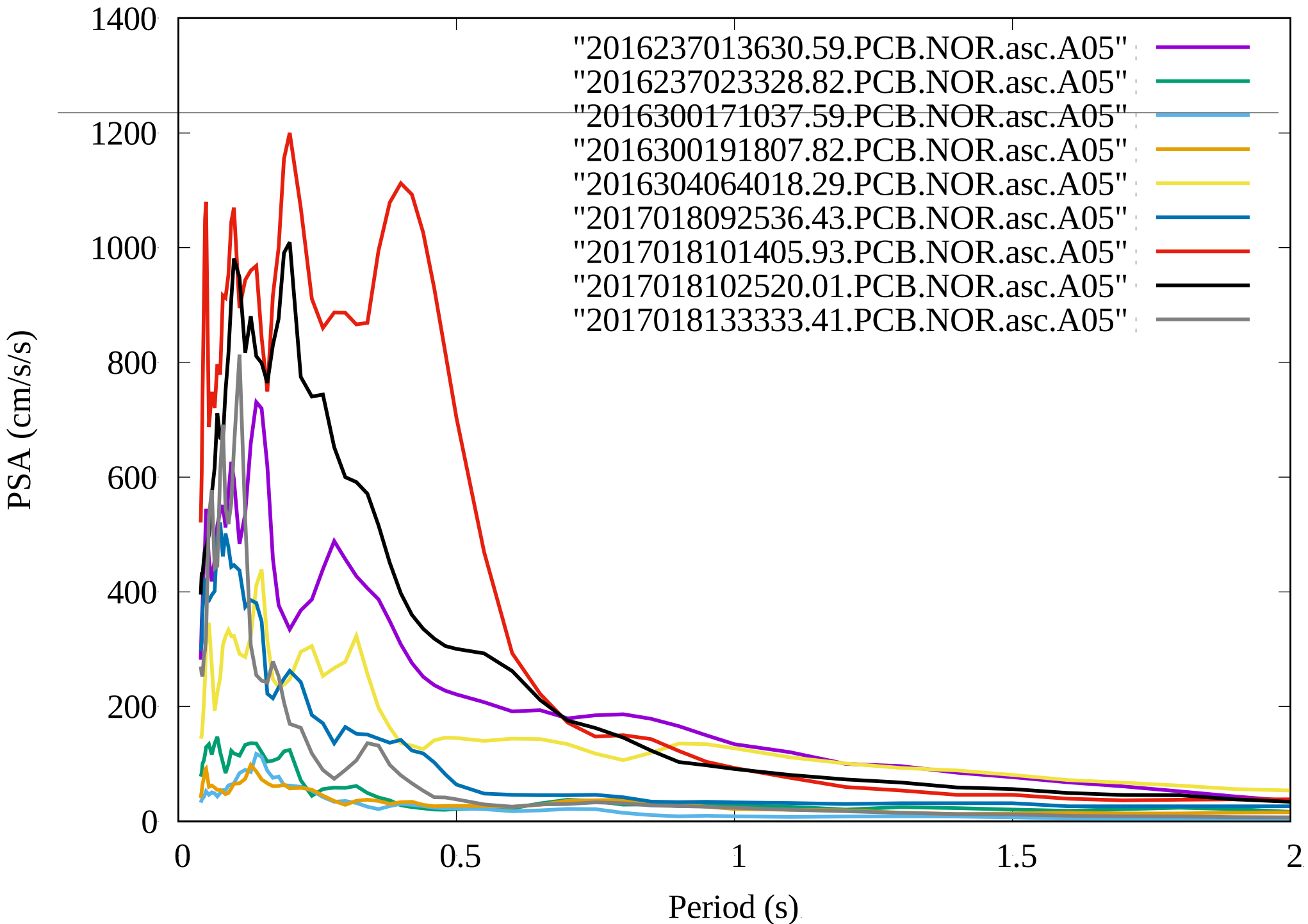


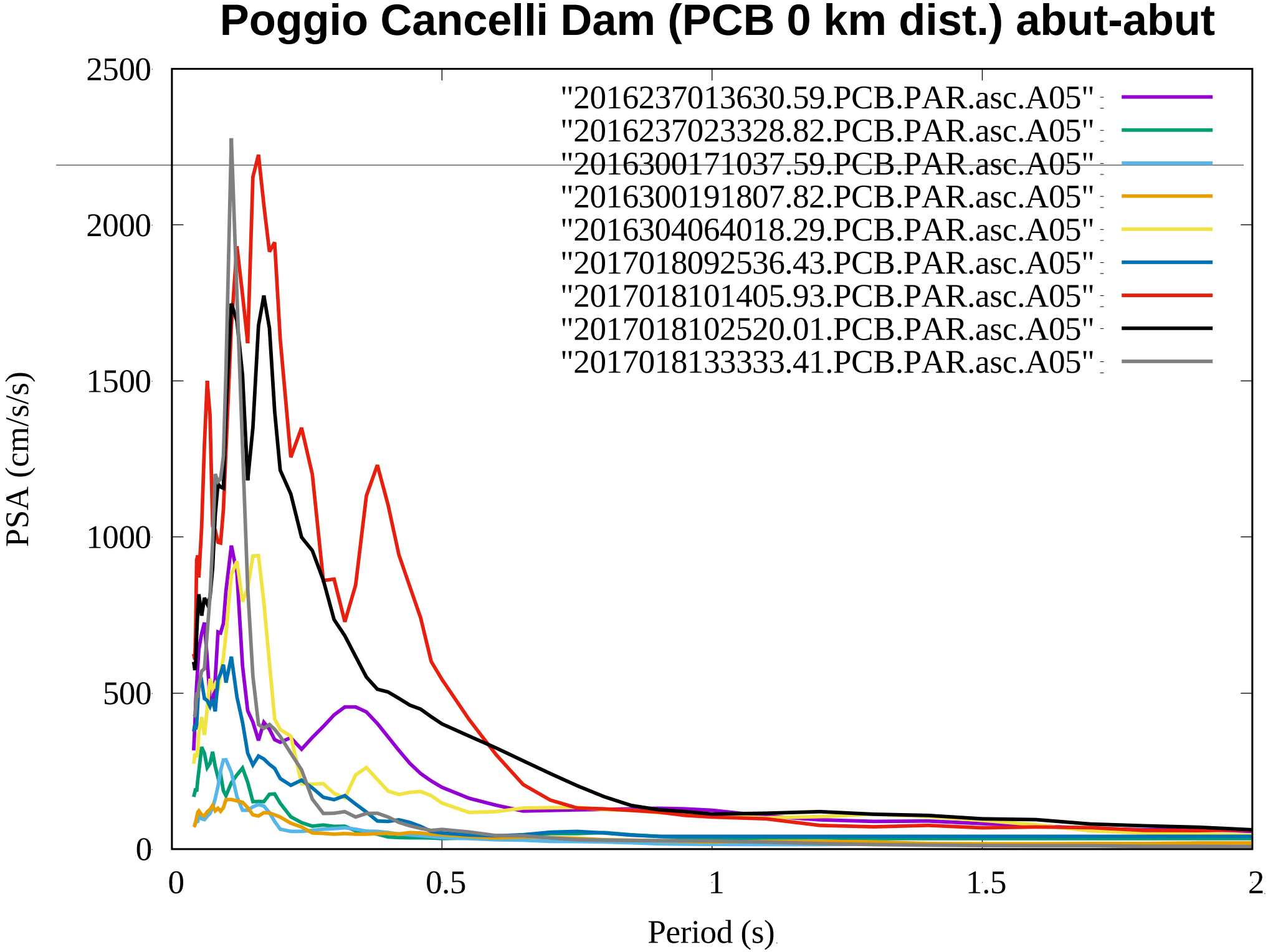


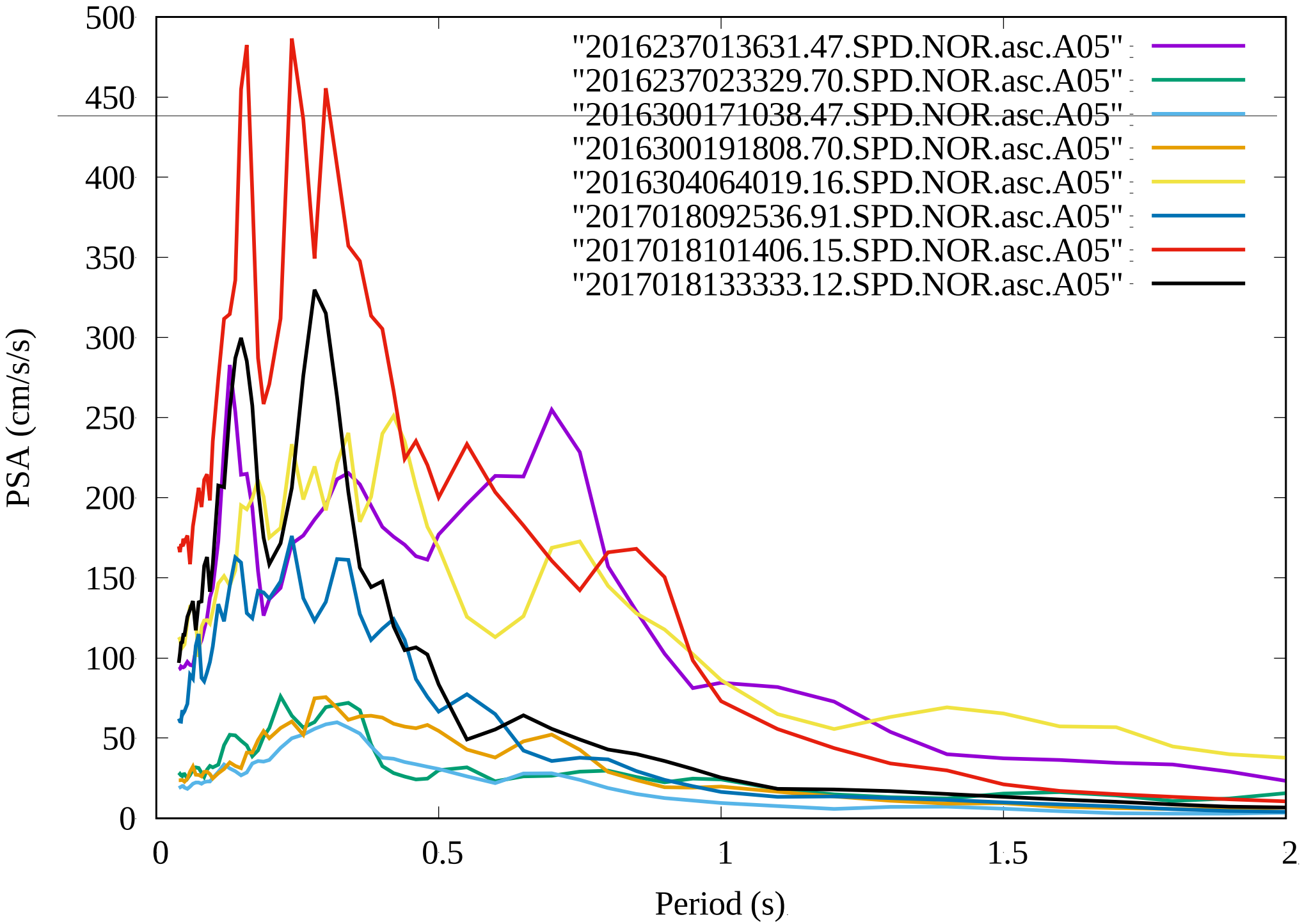
- 15 velocimeters deployed at the dam crest
- 2 hrs. ambient vibration measurement (12 Nov. 2016)
- spectral analysis and peak picking
- comparison of modal frequencies and deformed shapes with historical data (1988 and 1993): forced vibration transfer functions
- good agreement of dynamical parameter before and after the 2016 earthquake

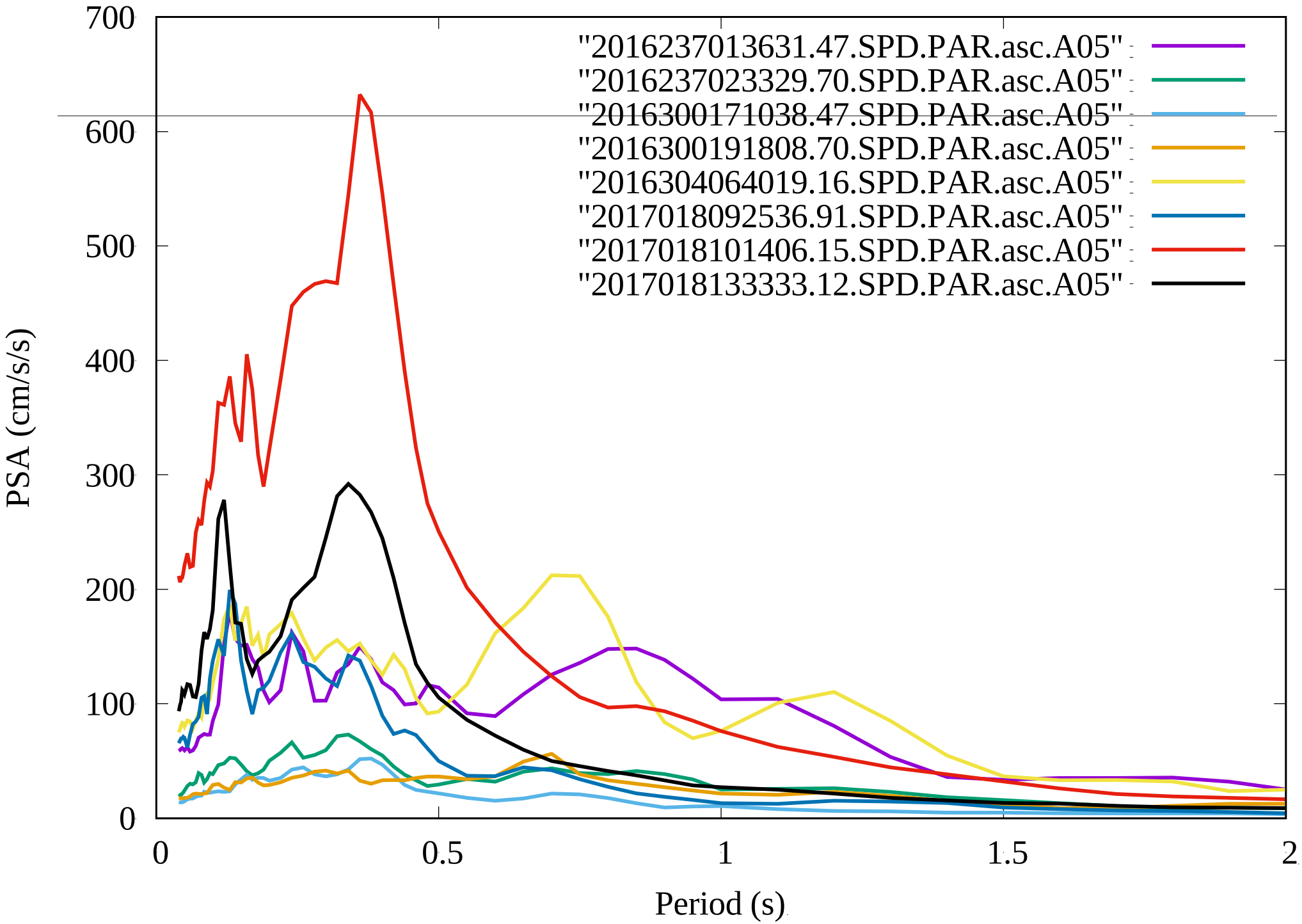

Fiastrone Dam (MNF 0 km dist.) upstr-downstr
PSA (cm/s/s)
Period (s)
0
50
100
150
200
250
300
350
400
450
0
0.5
1
1.5
2
"2016237013633.87.MNF.NOR.asc.A05"
"2016237023328.75.MNF.NOR.asc.A05"
"2016300171034.56.MNF.NOR.asc.A05"
"2016300191803.58.MNF.NOR.asc.A05"
"2016304064016.46.MNF.NOR.asc.A05"
"2017018092544.53.MNF.NOR.asc.A05"
"2017018101414.45.MNF.NOR.asc.A05"
"2017018102528.98.MNF.NOR.asc.A05"
"2017018133342.18.MNF.NOR.asc.A05"
Modes 1-3


Fiastrone Dam (MNF 0 km dist.) abut-abut
PSA (cm/s/s)
Period (s)
0
50
100
150
200
250
300
350
400
450
0
0.5
1
1.5
2
"2016237013633.87.MNF.PAR.asc.A05"
"2016237023328.75.MNF.PAR.asc.A05"
"2016300171034.56.MNF.PAR.asc.A05"
"2016300191803.58.MNF.PAR.asc.A05"
"2016304064016.46.MNF.PAR.asc.A05"
"2017018092544.53.MNF.PAR.asc.A05"
"2017018101414.45.MNF.PAR.asc.A05"
"2017018102528.98.MNF.PAR.asc.A05"
"2017018133342.18.MNF.PAR.asc.A05"
Modes 1-3


Poggio Cancelli Dam (PCB 0 km dist.) upstr-downstr
"2016237013630.59.PCB.NOR.asc.A05"
"2016237023328.82.PCB.NOR.asc.A05"
"2016300171037.59.PCB.NOR.asc.A05"
"2016300191807.82.PCB.NOR.asc.A05"
"2016304064018.29.PCB.NOR.asc.A05"
"2017018092536.43.PCB.NOR.asc.A05"
"2017018101405.93.PCB.NOR.asc.A05"
"2017018102520.01.PCB.NOR.asc.A05"
"2017018133333.41.PCB.NOR.asc.A05"
PSA (cm/s/s)
Period (s)
0
200
400
600
800
1000
1200
1400
0
0.5
1
1.5
2


Poggio Cancelli Dam (PCB 0 km dist.) abut-abut
"2016237013630.59.PCB.PAR.asc.A05"
"2016237023328.82.PCB.PAR.asc.A05"
"2016300171037.59.PCB.PAR.asc.A05"
"2016300191807.82.PCB.PAR.asc.A05"
"2016304064018.29.PCB.PAR.asc.A05"
"2017018092536.43.PCB.PAR.asc.A05"
"2017018101405.93.PCB.PAR.asc.A05"
"2017018102520.01.PCB.PAR.asc.A05"
"2017018133333.41.PCB.PAR.asc.A05"
PSA (cm/s/s)
2500
2000
1500
1000
500
0
0
0.5
1
1.5
2
Period (s)


Sella Pedicate Dam (SPD 0 km dist.) upstr-downstr
"2016237013631.47.SPD.NOR.asc.A05"
"2016237023329.70.SPD.NOR.asc.A05"
"2016300171038.47.SPD.NOR.asc.A05"
"2016300191808.70.SPD.NOR.asc.A05"
"2016304064019.16.SPD.NOR.asc.A05"
"2017018092536.91.SPD.NOR.asc.A05"
"2017018101406.15.SPD.NOR.asc.A05"
"2017018133333.12.SPD.NOR.asc.A05"
PSA (cm/s/s)
Period (s)
0
50
100
150
200
250
300
350
400
450
500
0
0.5
1
1.5
2


Sella Pedicate Dam (SPD 0 km dist.) abut-abut
"2016237013631.47.SPD.PAR.asc.A05"
"2016237023329.70.SPD.PAR.asc.A05"
"2016300171038.47.SPD.PAR.asc.A05"
"2016300191808.70.SPD.PAR.asc.A05"
"2016304064019.16.SPD.PAR.asc.A05"
"2017018092536.91.SPD.PAR.asc.A05"
"2017018101406.15.SPD.PAR.asc.A05"
"2017018133333.12.SPD.PAR.asc.A05"
PSA (cm/s/s)
Period (s)
0
100
200
300
400
500
600
700
0
0.5
1
1.5
2

THANKS FOR YOUR ATTENTION