Antelope User Group meeting
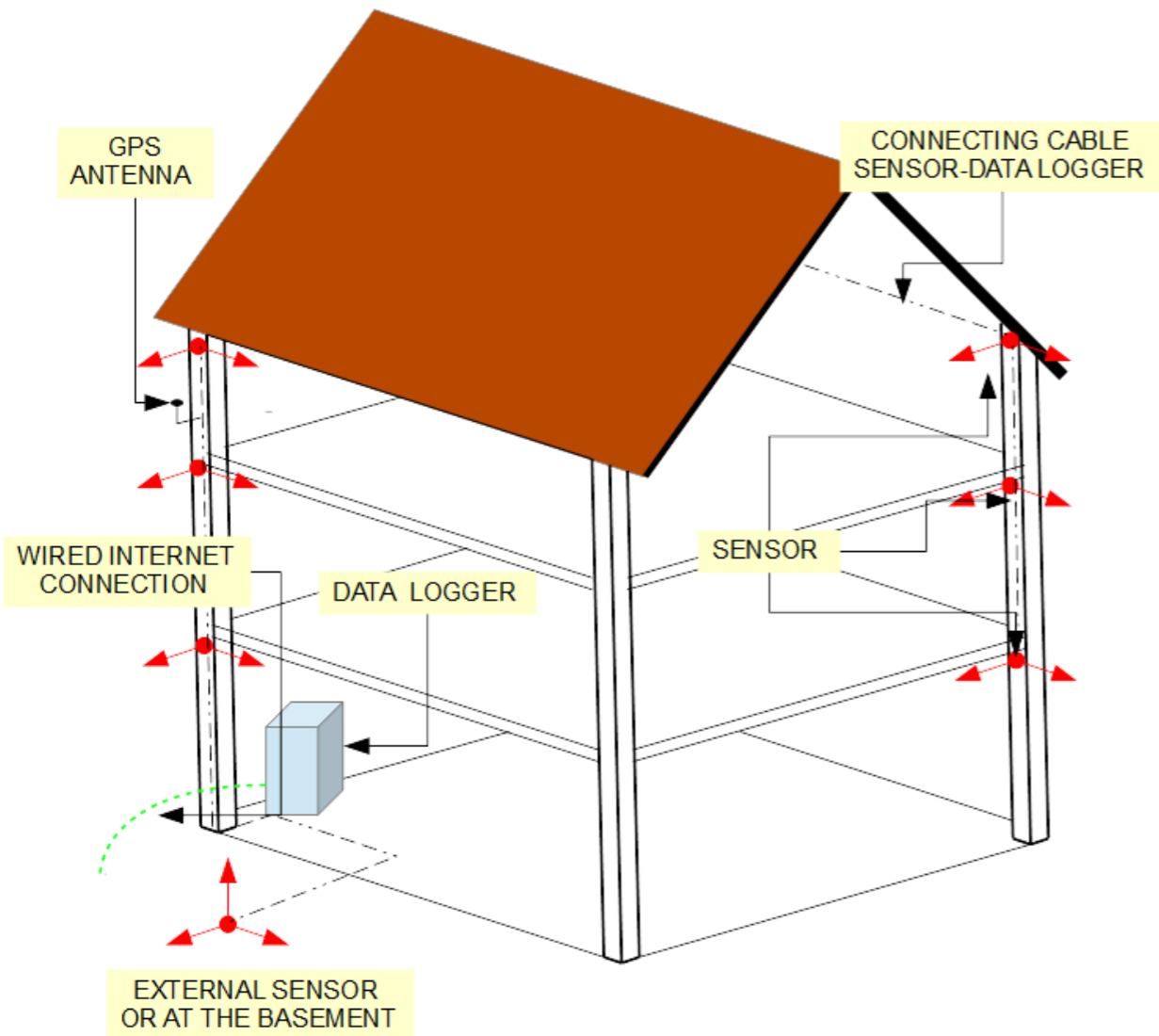DPC– via Vitorchiano 2-4 - Rome – Italy
May 18th to 20th , 2016

The data processing methodology for the Seismic Observatory of Structures (OSS)

Daniele Spina
DPC - Ufficio Rischio Sismico e Vulcanico
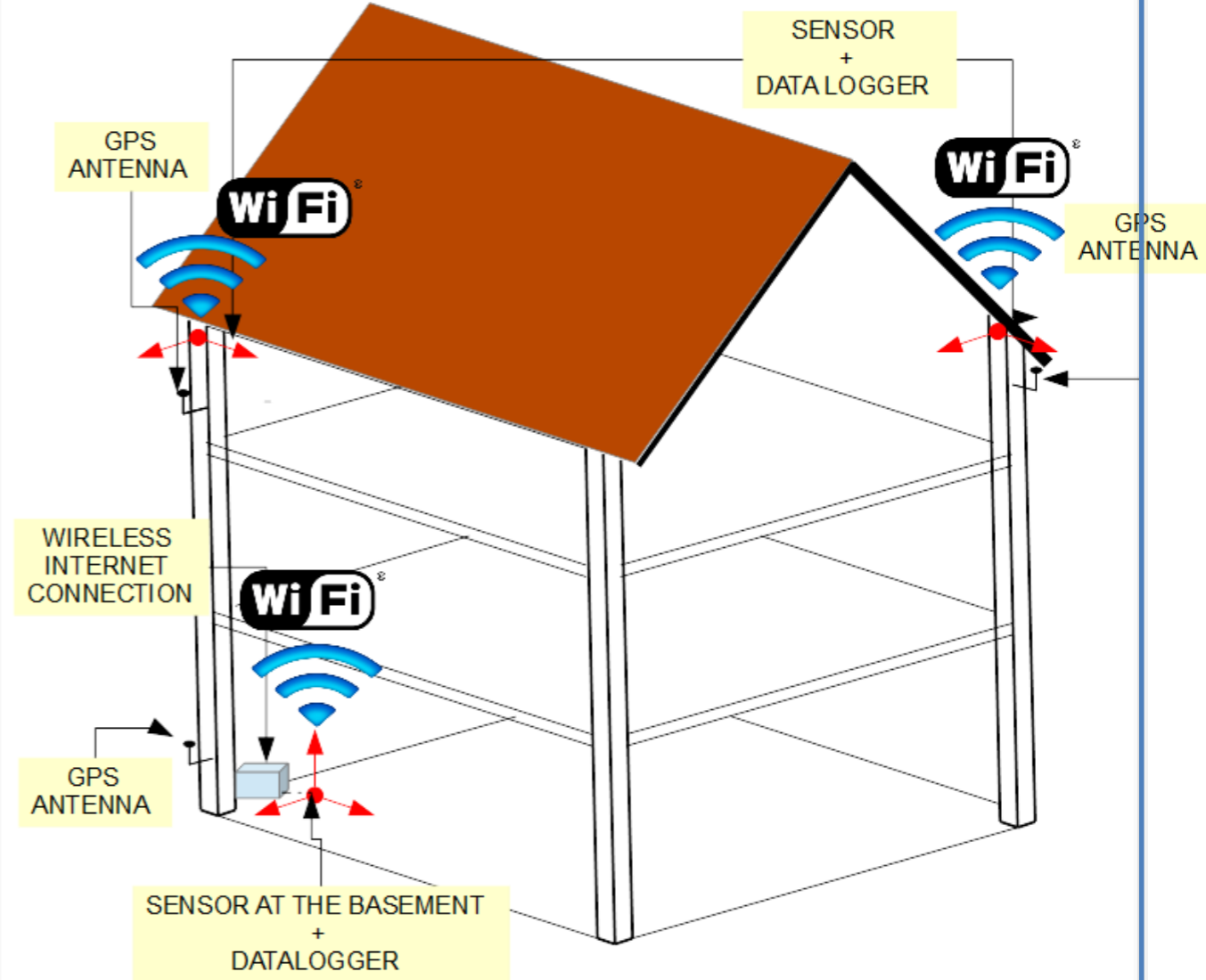
PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

1   2   3   4   5

```
01BSP   52.191503 4.437122   1632-11-24   20.04.92   200
 3.8743931e-03   -8.4208961e-03   -2.4543166e-03   -1.2642465e-03    5.6984715e-04   -7.2909788e-03    4.5393888e-05
                          2e-02    1.3075165e-02    2.7256368e-03    5.5629192e-03   -5.4485236e-03
                      9e-03   -7.0927009e-03    3.6888095e-03   -7.6397307e-03    1.4763563e-02
                      0e-04   -2.3740677e-03    4.7733740e-03   -2.8840886e-03   -2.6538937e-02
-6.1524317e-03                                            2.1934384e-02    6.7433474e-03    4.0792846e-03
-8.0011416e-04                                            9.9033149e-03    2.5938775e-03   -5.0230192e-03
-5.1193688e-03                                            3.5239656e-03   -1.4513076e-04    5.6955206e-03
 2.5128608e-03    1.1745325e-02    1.35                        3.7312762e-03    2.8215008e-03    7.4488088e-03
 1.3413209e-02   -4.4472550e-03   -4.40                        3.4016340e-03   -1.2487075e-02   -1.3497211e-02
 1.1483816e-02   -1.5367450e-02    6.99                        6.2637182e-03   -1.1566966e-02   -4.4760717e-03
 8.4346570e-03    8.7818530e-03    1.1895218e-02   -4.4550068e-03    8.9594336e-03   -4.0243450e-03   -3.8927556e-03
 5.3316086e-04    4.0949641e-03   -1.1469688e-02    8.1                        2e-04    5.4530746e-03
 2.5608789e-04    1.3006505e-03   -5.1248876e-03   -2.8                        5e-03   -1.0030253e-02
 1.0316055e-03    1.0396552e-02    1.6591833e-02    1.1                        1e-02    1.7867002e-02
 2.0520973e-02    2.6477959e-03    2.5463687e-04   -1.2967042e-03                                1e-04
 1.5777538e-02    1.1154310e-02   -1.7512771e-03    6.0841853e-03                                7e-03
-1.6523360e-02    8.7424354e-03   -3.4731337e-03   -6.3596745e-03                                5e-04
-5.2322456e-03   -8.0463774e-03    5.1638285e-03    1.0850228e-02    4.9788496e-03   -4.8081883e-03   -2.3262332e-03
-2.1691209e-03   -1.2393558e-02   -1.2114368e-02    2.7696255e-03    3.4091863e-03    8.6695957e-03   -4.1274587e-03
 9.8547843e-03   -1.2718203e-02   -7.0134576e-03    6.6418445e-03    5.0983160e-03   -1.6606248e-02   -7.2705851e-03
 5.2946441e-03    1.2869550e-02    2.7300299e-02   -1.2217335e-02   -1.6627345e-02   -1.4853159e-02   -6.7022325e-03
-3.3841209e-03   -6.0912599e-04    1.2929575e-02   -2.5013692e-03   -4.3794712e-03   -1.2324700e-02    1.7286698e-03
-4.2107481e-03    4.0477285e-03   -1.9389971e-03    1.3911031e-03    6.2697148e-03   -4.1175517e-03    1.1007231e-02
-7.8600719e-03   -5.3657383e-03   -6.0281872e-03    9.1816957e-04    6.9126012e-03    8.6154316e-03   -1.9285540e-02
-1.1608380e-03    7.8230579e-03   -2.8204376e-03    2.1401748e-02    1.5897284e-02   -1.9812361e-02   -1.2866881e-03
```
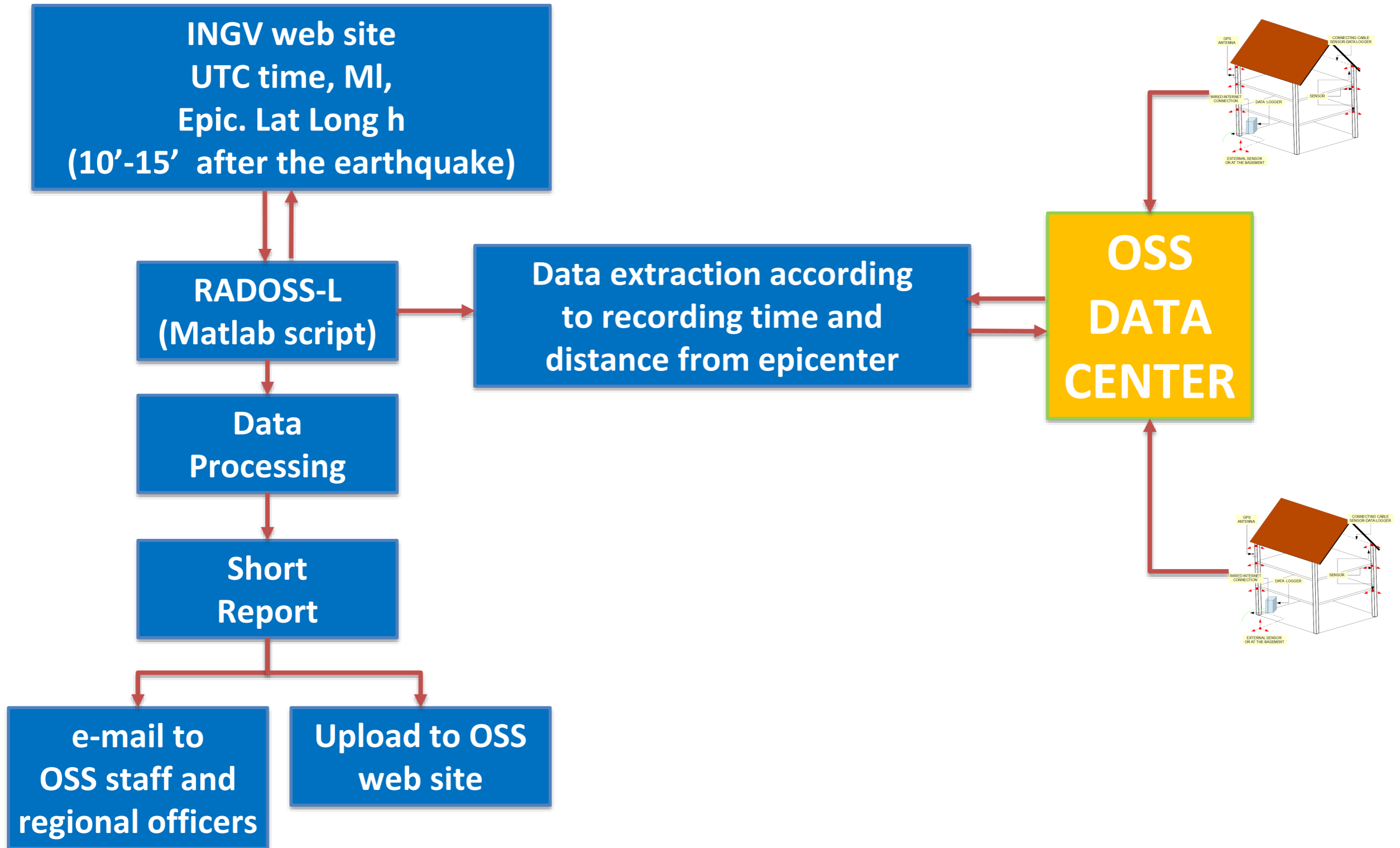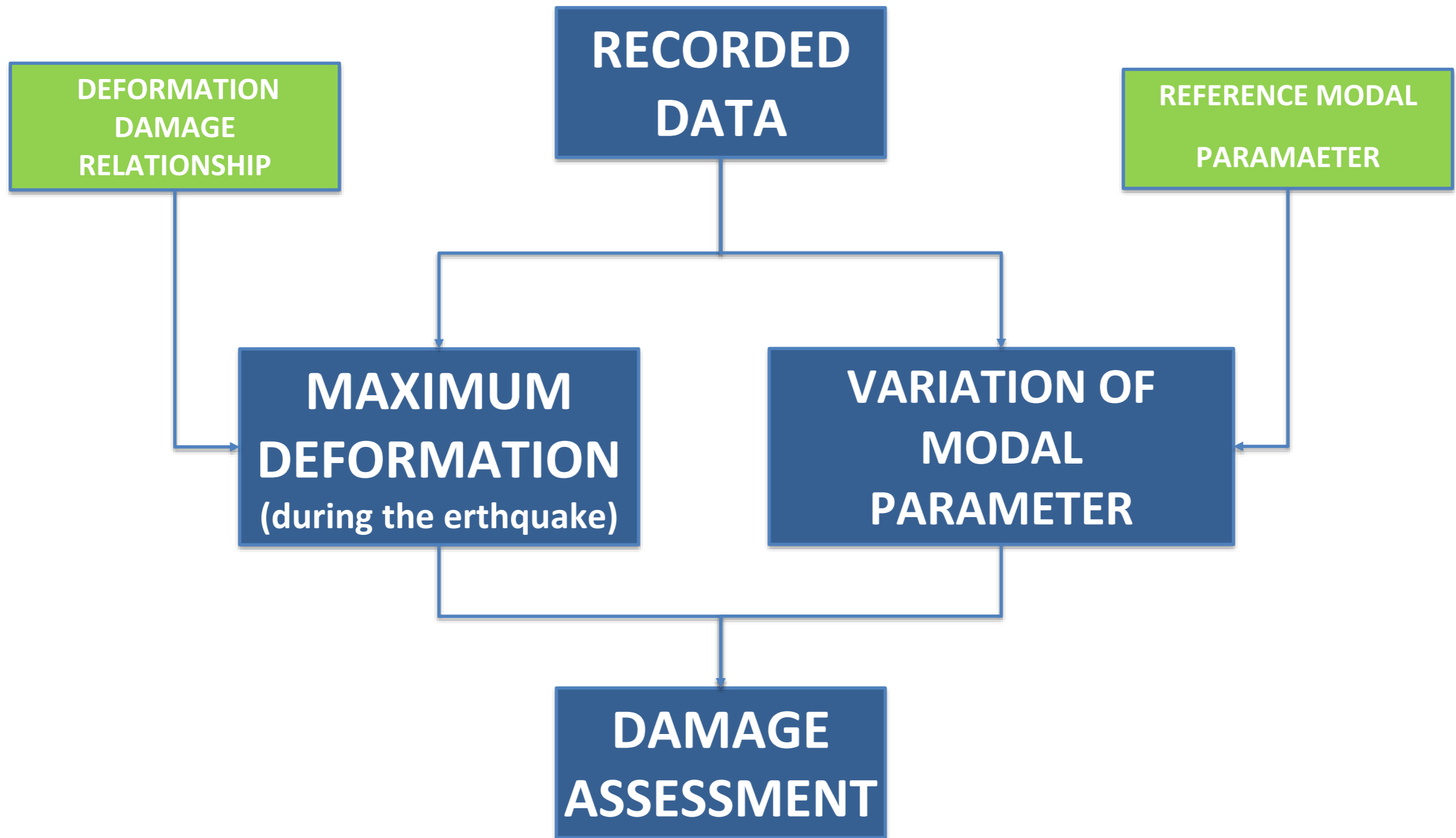
1. Station short name

2. Geographic Coordinates

3. Trigger Date

4. Trigger UTC Time
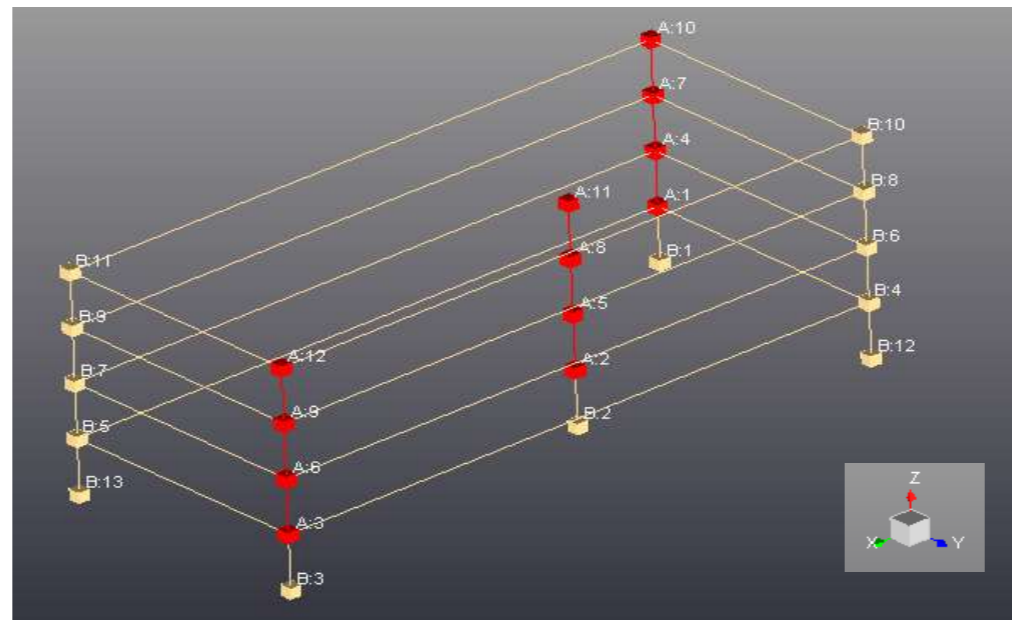
5. Sampling Frequency

6

6. Recorded physical signal

INGV web site
UTC time, Ml,
Epic. Lat Long h
(10'-15' after the earthquake)

RADOSS-L
(Matlab script)

Data extraction according to recording time and distance from epicenter

OSS DATA CENTER

Data Processing

Short Report

e-mail to OSS staff and regional officers

Upload to OSS web site

4

Channel → DOF

Hospital of Sanremo

sensors layout (red)

Channel *vs* dof

	Response DOF
1	A:1:+X
2	A:1:+Y
3	A:2:+Y
4	A:3:+X
5	A:3:+Y
6	A:4:+X
7	A:4:+Y
8	A:5:+Y
9	A:6:+X
10	A:6:+Y
11	A:7:+X
12	A:7:+Y
13	A:8:+Y
14	A:9:+X
15	A:9:+Y
16	A:10:+X
17	A:10:+Y
18	A:11:+Y
19	A:12:+X
20	A:12:+Y

Coordinates of the measurement points

	Parent Comp...	Name	Full Name	X (m)	Y (m)	Z (m)	XY (°)	XZ (°)	YZ (°)
1	A	1	A:1	0.0000	0.0000	3.5000	0.0000	0.0000	0.0000
2	A	2	A:2	15.0000	11.0000	3.5000	0.0000	0.0000	0.0000
3	A	3	A:3	37.0000	15.2000	3.5000	0.0000	0.0000	0.0000
4	A	4	A:4	0.0000	0.0000	7.0000	0.0000	0.0000	0.0000
5	A	5	A:5	15.0000	11.0000	7.0000	0.0000	0.0000	0.0000
6	A	6	A:6	37.0000	15.2000	7.0000	0.0000	0.0000	0.0000
7	A	7	A:7	0.0000	0.0000	10.5000	0.0000	0.0000	0.0000
8	A	8	A:8	15.0000	11.0000	10.5000	0.0000	0.0000	0.0000
9	A	9	A:9	37.0000	15.2000	10.5000	0.0000	0.0000	0.0000
10	A	10	A:10	0.0000	0.0000	14.0000	0.0000	0.0000	0.0000
11	A	11	A:11	15.0000	11.0000	14.0000	0.0000	0.0000	0.0000
12	A	12	A:12	37.0000	15.2000	14.0000	0.0000	0.0000	0.0000
13	A		A	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
14	A		A	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

ambient vibrations → modal parameters
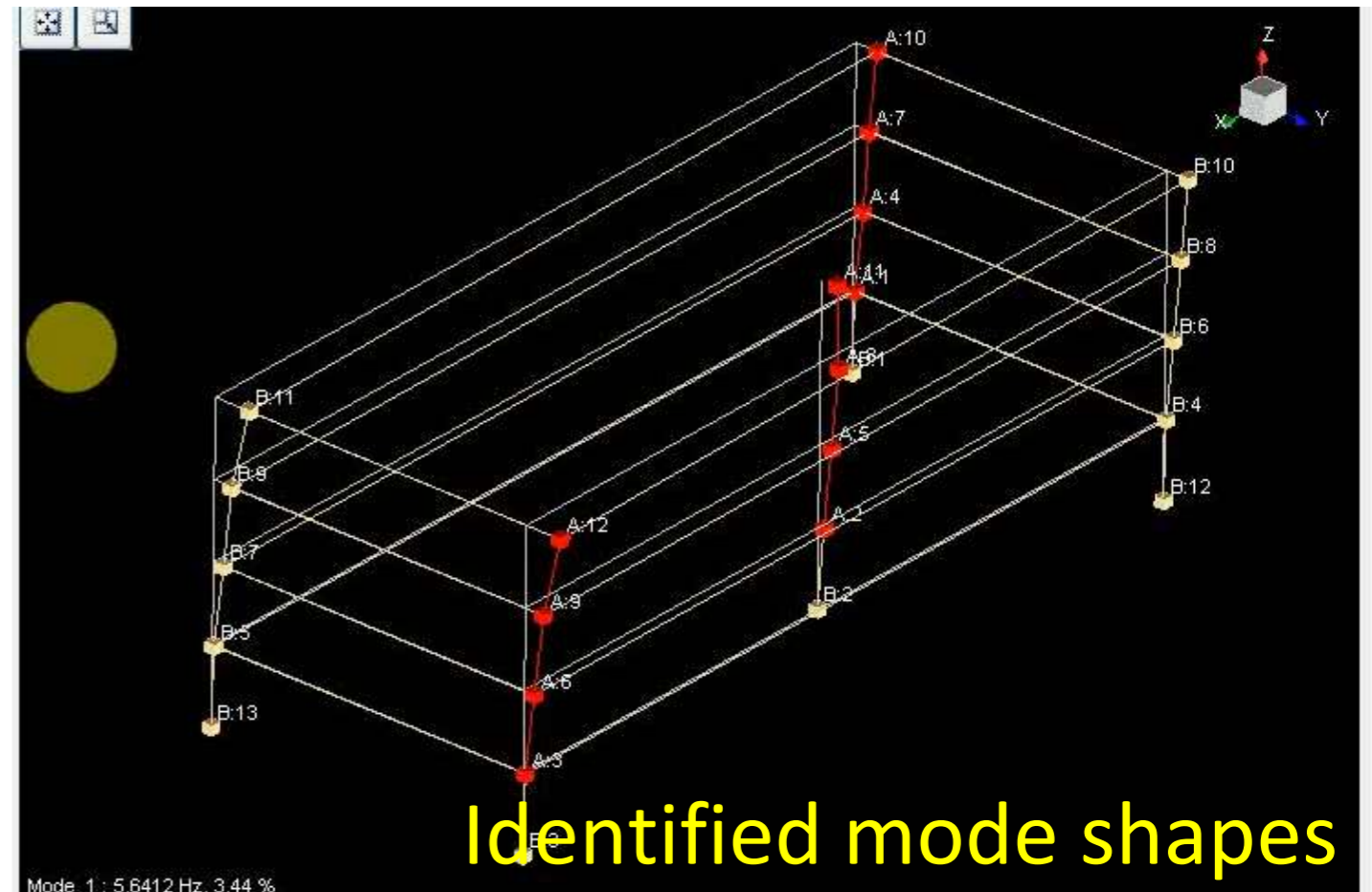
cross-spectra
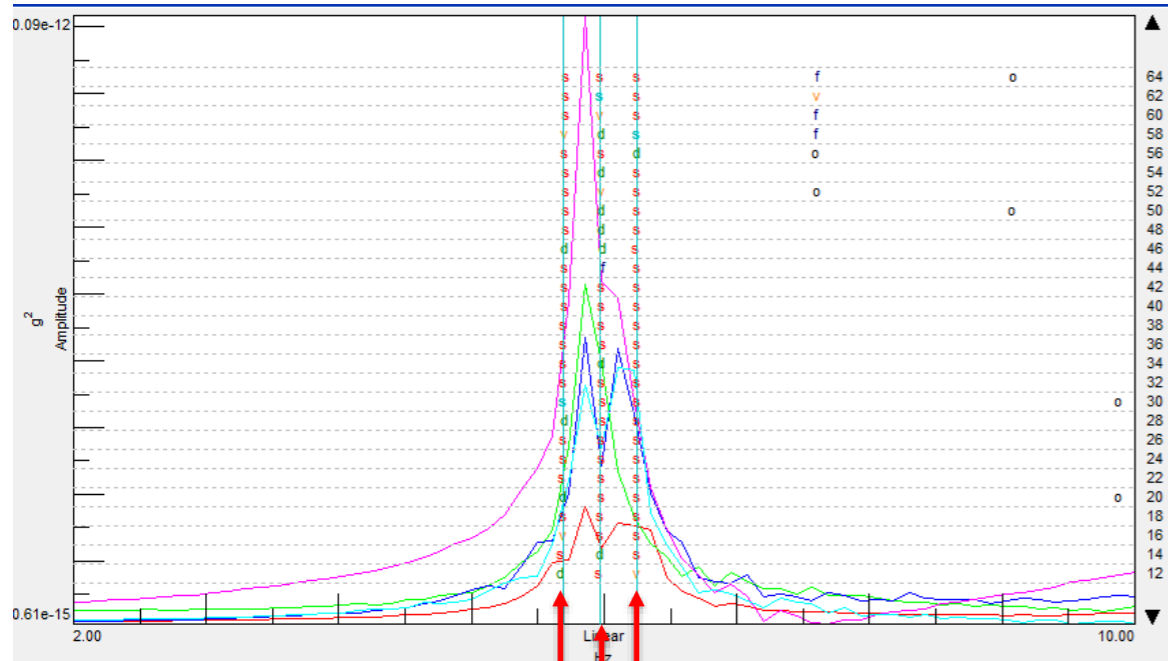
stable poles

Mode 1 : 5.696 Hz, 2.82 % s

Mode 2 : 5.970 Hz, 1.89 % s

Mode 3 : 6.249 Hz, 1.53 % s

Identified mode shapes

Mode 1 : 5.6412 Hz, 3.44 %

Damage indexes based on modal parameter variation
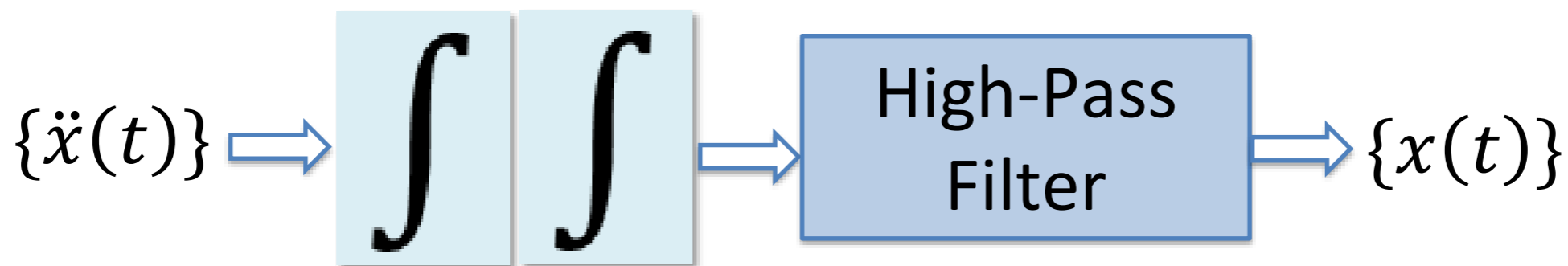
Percentage **F**requency **C**hange

$$\frac{\Delta f_k}{f_k} = \frac{f_k^d - f_k}{f_k}$$

Modal **A**ssurance **C**riterion

$$MAC_k(\phi_k, \phi_k^d) = \frac{<\phi_k, \phi_k^d>^2}{<\phi_k, \phi_k><\phi_k^d, \phi_k^d>}$$

accelerations $\longrightarrow$ deformations

$$\{\ddot{x}(t)\} \Rightarrow \boxed{\int} \boxed{\int} \Rightarrow \boxed{\text{High-Pass Filter}} \Rightarrow \{x(t)\}$$

$$\{\epsilon(t)\} = [D]\{x(t)\}$$

$\{\ddot{x}(t)\}$ Acceletation [LT^{-2}]

$\{x(t)\}$ Displacement [L]

$[D]$ Kinematic compatibility matrix [L^{-1}]

$\{\epsilon(t)\}$ Deformation [L^{0}]
$\qquad\qquad\qquad \{\epsilon(t)\} = [D]\{x(t)\}$

Simplified System

m_3

x_3

K_{32}

m_2

x_2

K_{21}

m_1

x_1

K_{10}

x_0

h

h

h
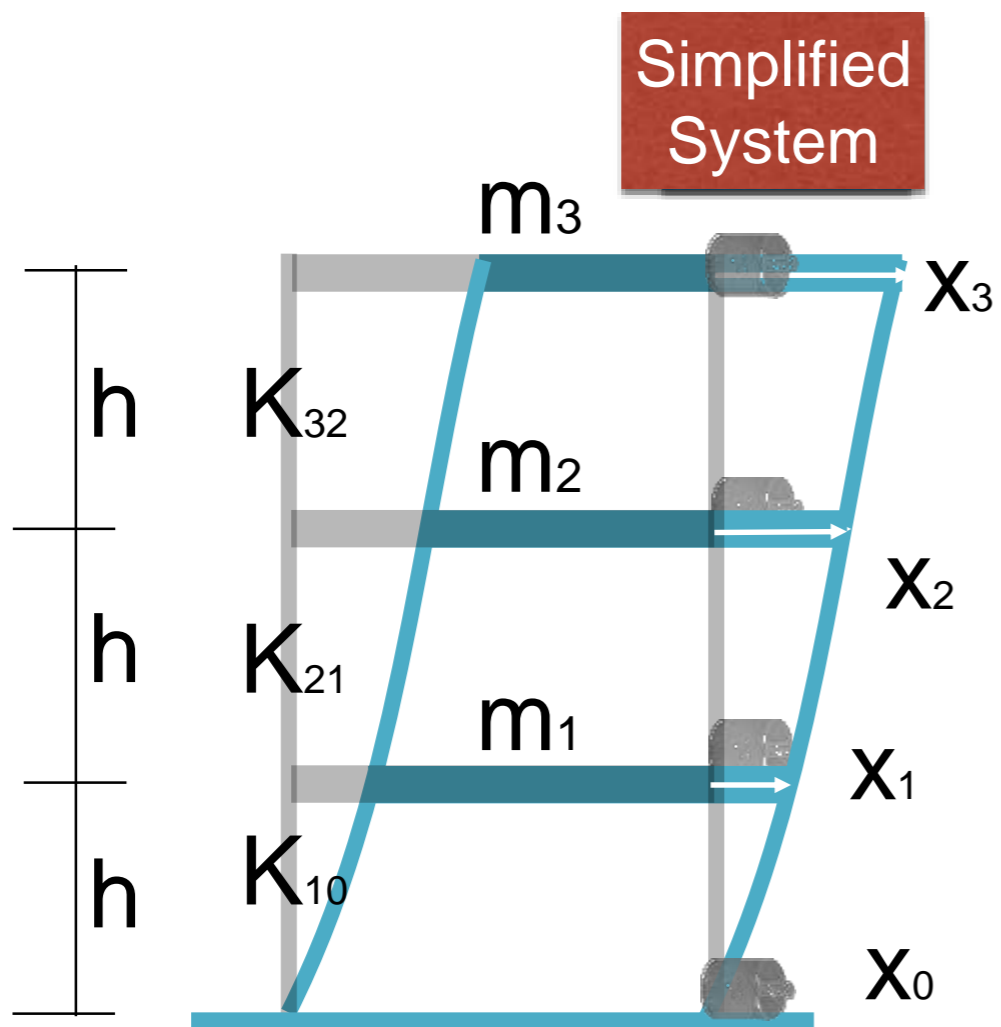
Kinematic compatibility matrix

$$[D] = \begin{bmatrix} -1/h & 1/h & 0 & 0 \\ 0 & -1/h & 1/h & 0 \\ 0 & 0 & -1/h & 1/h \end{bmatrix}$$

Interstory drift

$$\epsilon_i = \delta_i = \frac{x_{i+1} - x_i}{h_i}$$

Damage parameter

detailed system:

$$\max(\delta_i) \quad i = 1, 2, 3$$
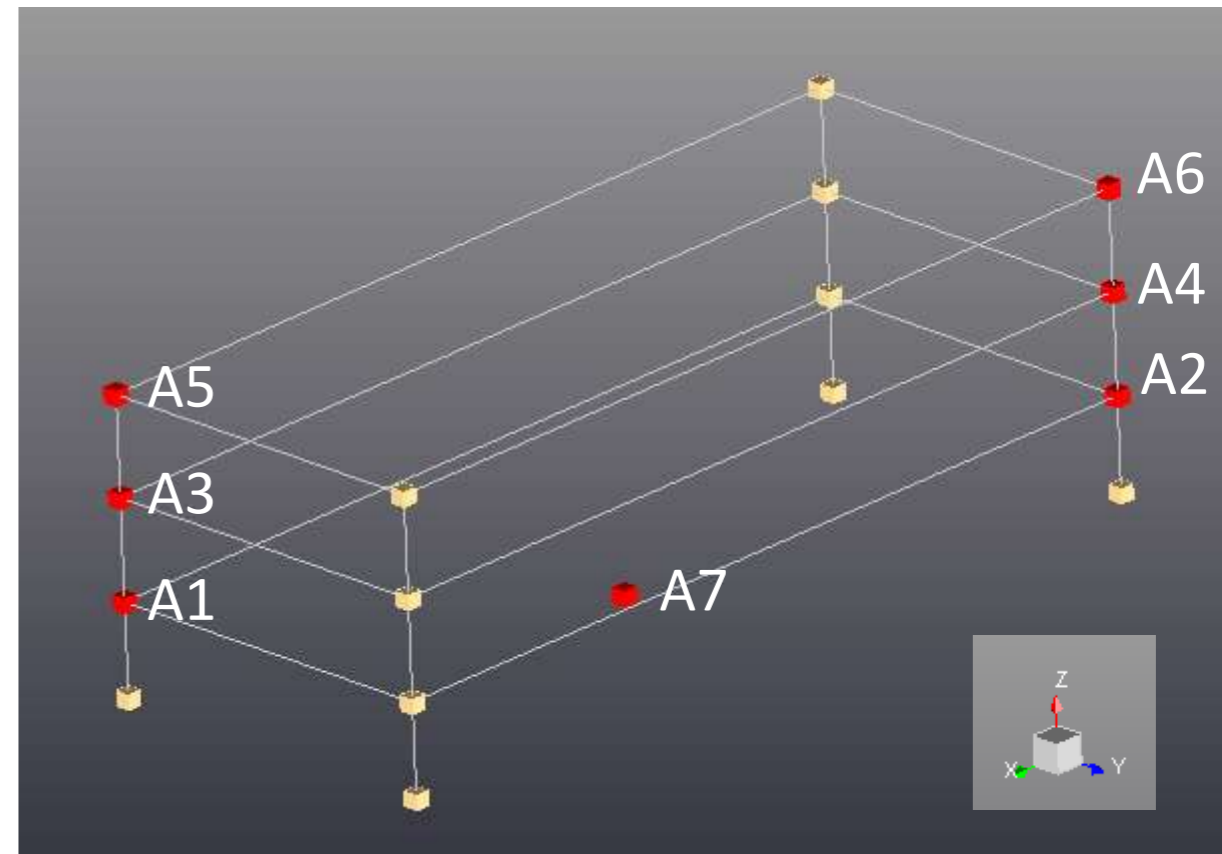
simplified system:

$$\bar{\delta} = \frac{x_3 - x_0}{3h}$$

http://www.mot1.it/ossdownload

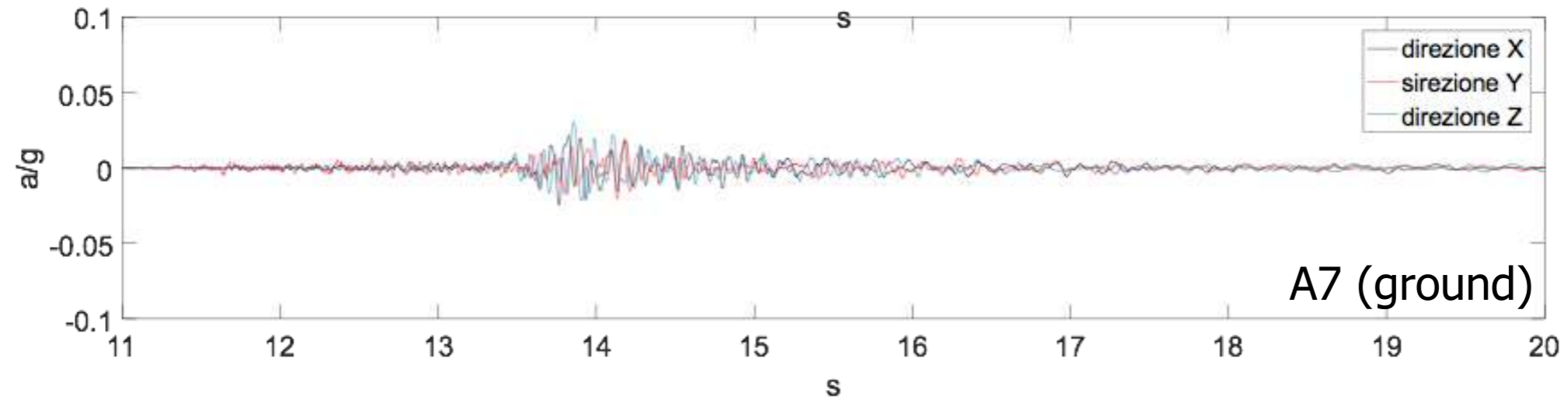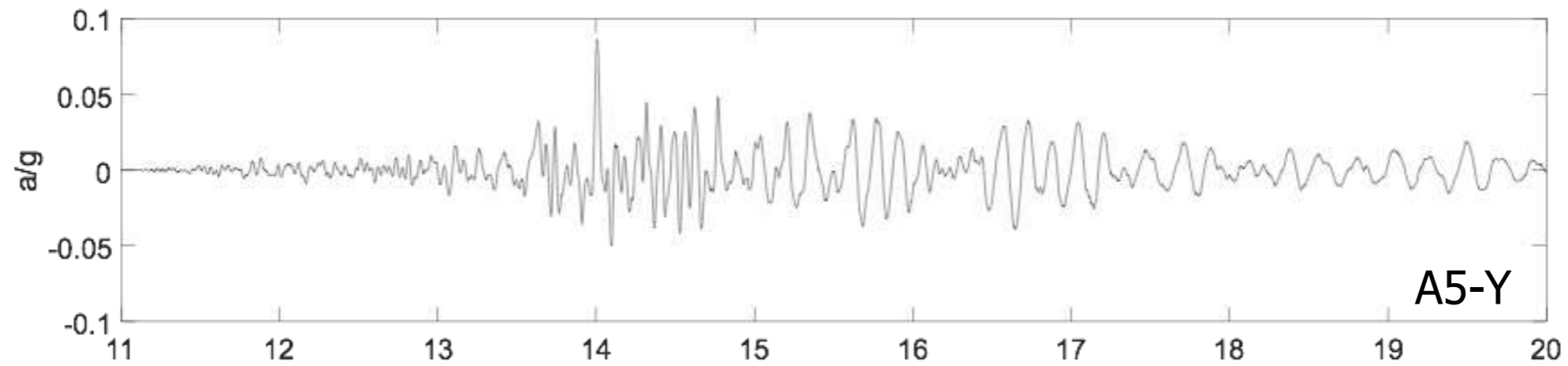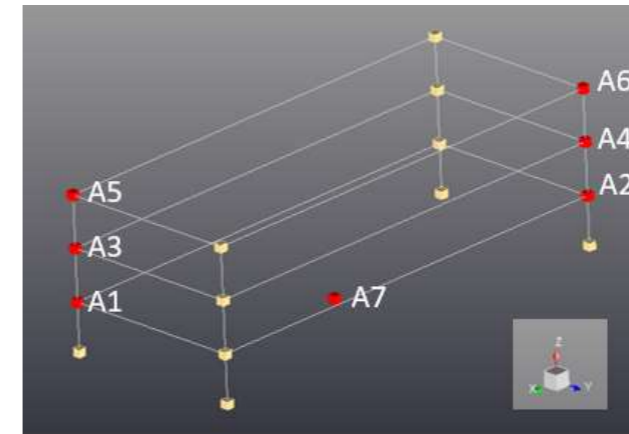OSSERVATORIO SISMICO DELLE STRUTTURE (OSS download service) 🖨

Elenco dei parametri - **Tempo origine:** 30/01/2015 00:45:49 - **Ml:** 4.10 - **Comune:** 33015 Moggio Udinese, Province of Udine, Italy

Sigla	Nome Stazione	Lat(°)	Lon(°)	Tipologia	Città	Dist (Km)	PGA x (g)	PGA y (g)	PGA z (g)	PSA x (g)	PSA y (g)	Dmax (x1000)
BC060	Scuola Media 'G. F. da Tolmezzo'	46.4042	13.0133	Edificio in c.a.	Tolmezzo	10	0.0248	0.0206	0.0309	0.0388	0.0859	0.13
BC055	Casa dello Studente	46.2792	13.1394	Edificio in c.a.	Gemona	15	0.0048	0.0040	0.0033	0.0074	0.0104	0.01
BC059	Municipio e Teatro di Pontebba	46.5087	13.3071	Edificio in muratura	Pontebba	17	0.0032	0.0041	0.0027	0.0090	0.0137	0.03
BC057	Municipio di San Daniele del Friuli	46.1614	13.0158	Edificio in muratura	San daniele del friuli	30	0.0015	0.0014	0.0010	0.0060	0.0057	0.00
BC054	Centro Scolastico Forni di Sopra	46.4230	12.5833	Edificio in muratura	Forni di sopra	43	0.0052	0.0033	0.0026	0.0149	0.0146	0.05
BC056	Scuola Media 'G. Marconi'	46.1661	12.7072	Edificio in c.a.	Maniago	43	0.0012	0.0011	0.0009	0.0057	0.0065	0.01

06/02/2015 08:52:27	38.70	13.16	256	4.7	Isole eolie (messina)	3	☑
30/01/2015 00:45:49	46.41	13.14	6	4.1	Udine	6	
	Vedi Parametri 🔍				Scarica Dati Evento ⬇		
23/01/2015 06:51:20	44.13	11.14	10	4.1	Bologna	3	☑

STRUCTURAL TYPOLOGY	R.C.
NUMBER OF FLOORS	3
NUMBER OF MEASURED ACC.	12
NUMBER OF DISP. TRASDUCER	2

COMPUTED INTERSTORY DRIFT

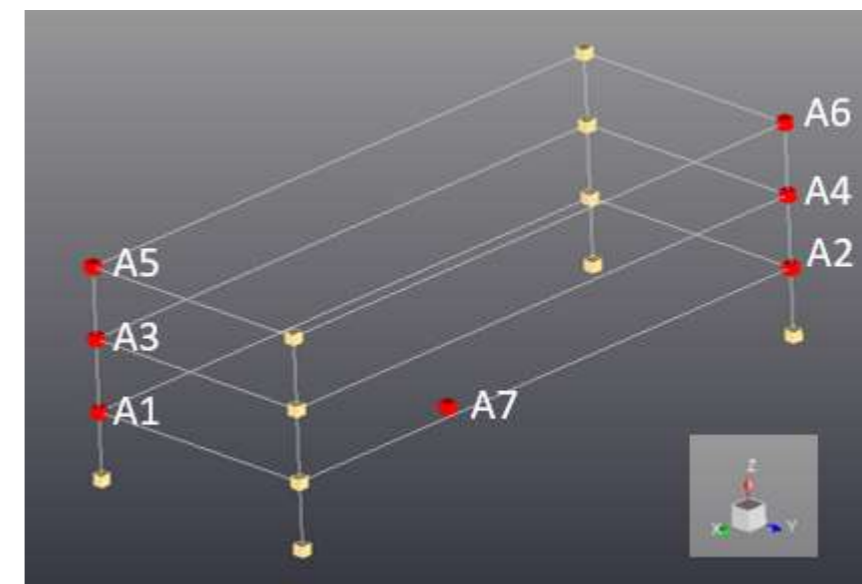**Drift Floor 3-2 A5–A3 Dir. X**
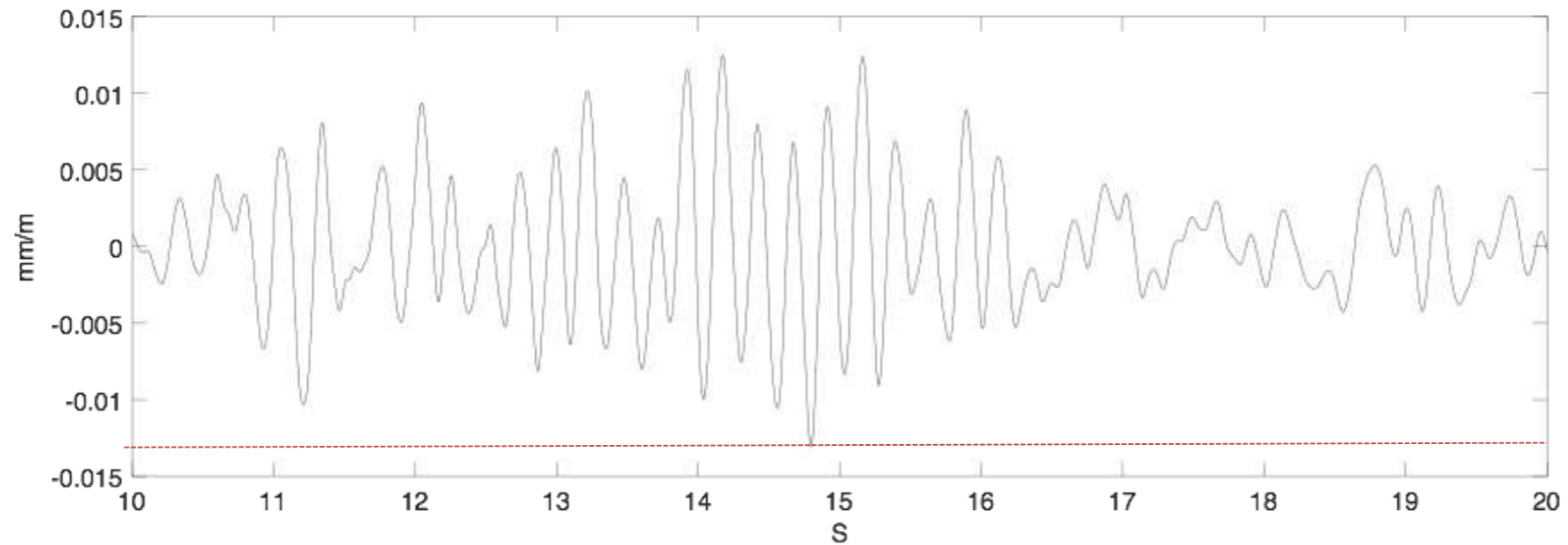
$$D_{SLO}=2 \times 10^{-3}$$

$$D_{max} << D_{SLO}$$

FLOOR	POINTS	DIRECTION	INTERSTORY DRIFT
1 - Ground	A1 - A7	X	0.11×10^{-3}
1 - Ground	A1 - A7	Y	0.10×10^{-3}
1- Ground	A2 – A7	Y	0.09×10^{-3}
2 - 1	A3 – A1	X	0.06×10^{-3}
2 - 1	A3 – A1	Y	0.03×10^{-3}
2 - 1	A4 – A2	Y	0.02×10^{-3}
3 – 2	A5 – A3	X	0.13×10^{-3}
3 - 2	A5 – A3	Y	0.09×10^{-3}
3 - 2	A6 – A4	Y	0.13×10^{-3}

14

Earthquake

Ambient post

f_1=4.09 Hz
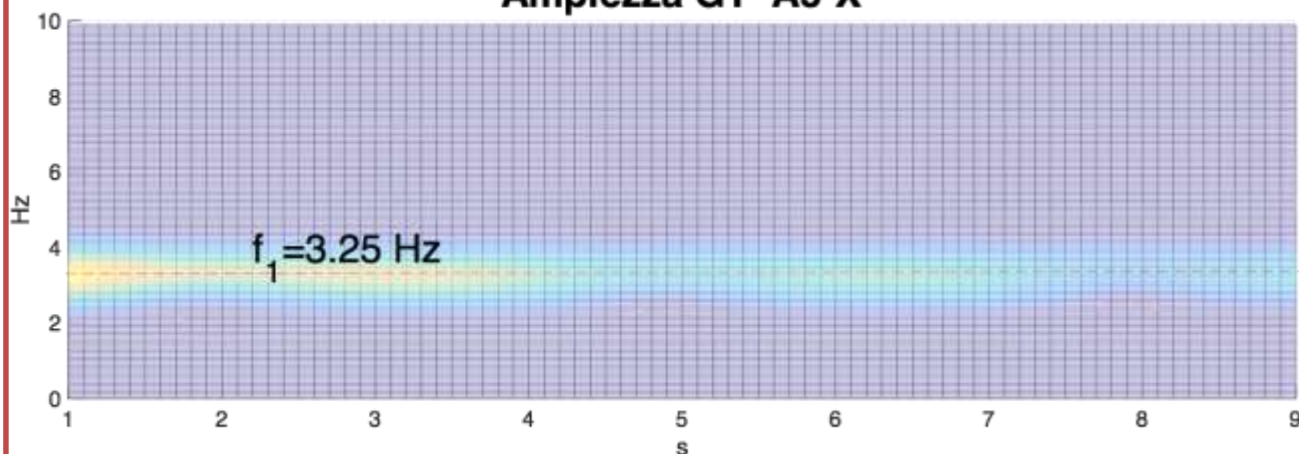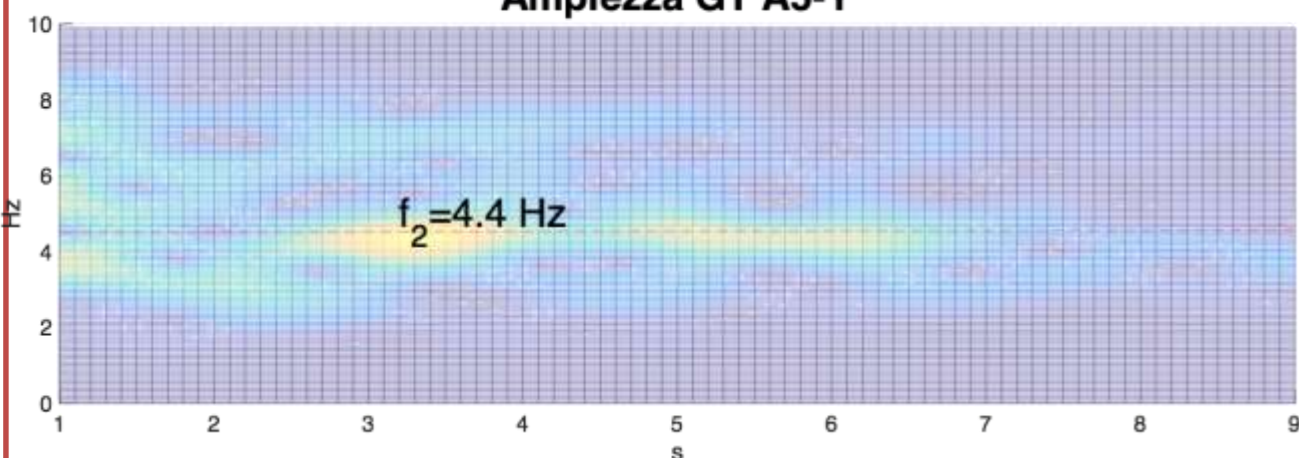
Freq. (Hz)	1	2	df 1 (%)	df 2 (%)
Amb. pre	4.19	5.21	-	-
Earthquake	3.25	4.40	-20.0	-14.0
Amb. post	4.09	5.13	-2.4	-1.6

15
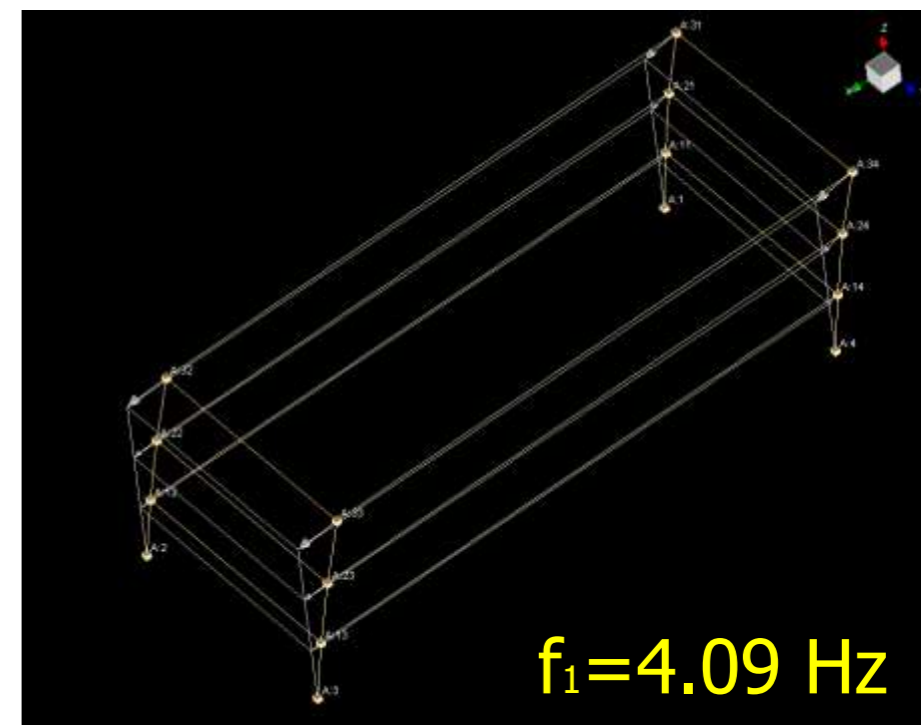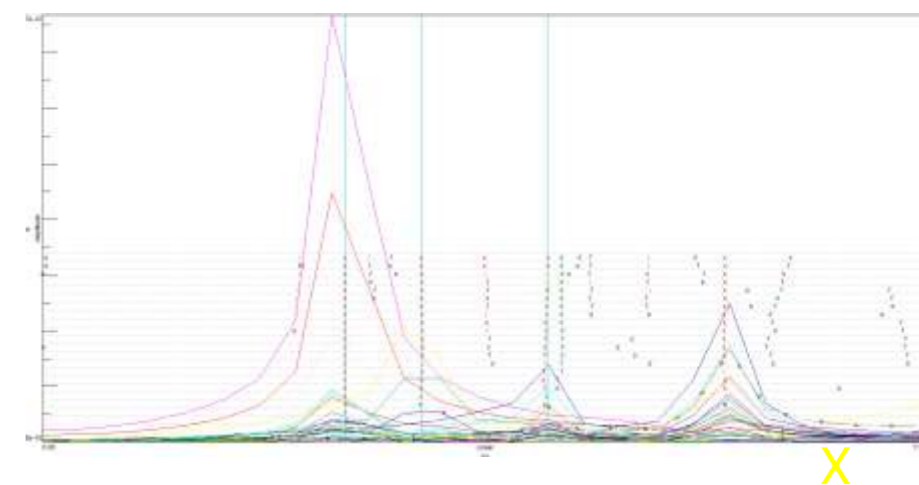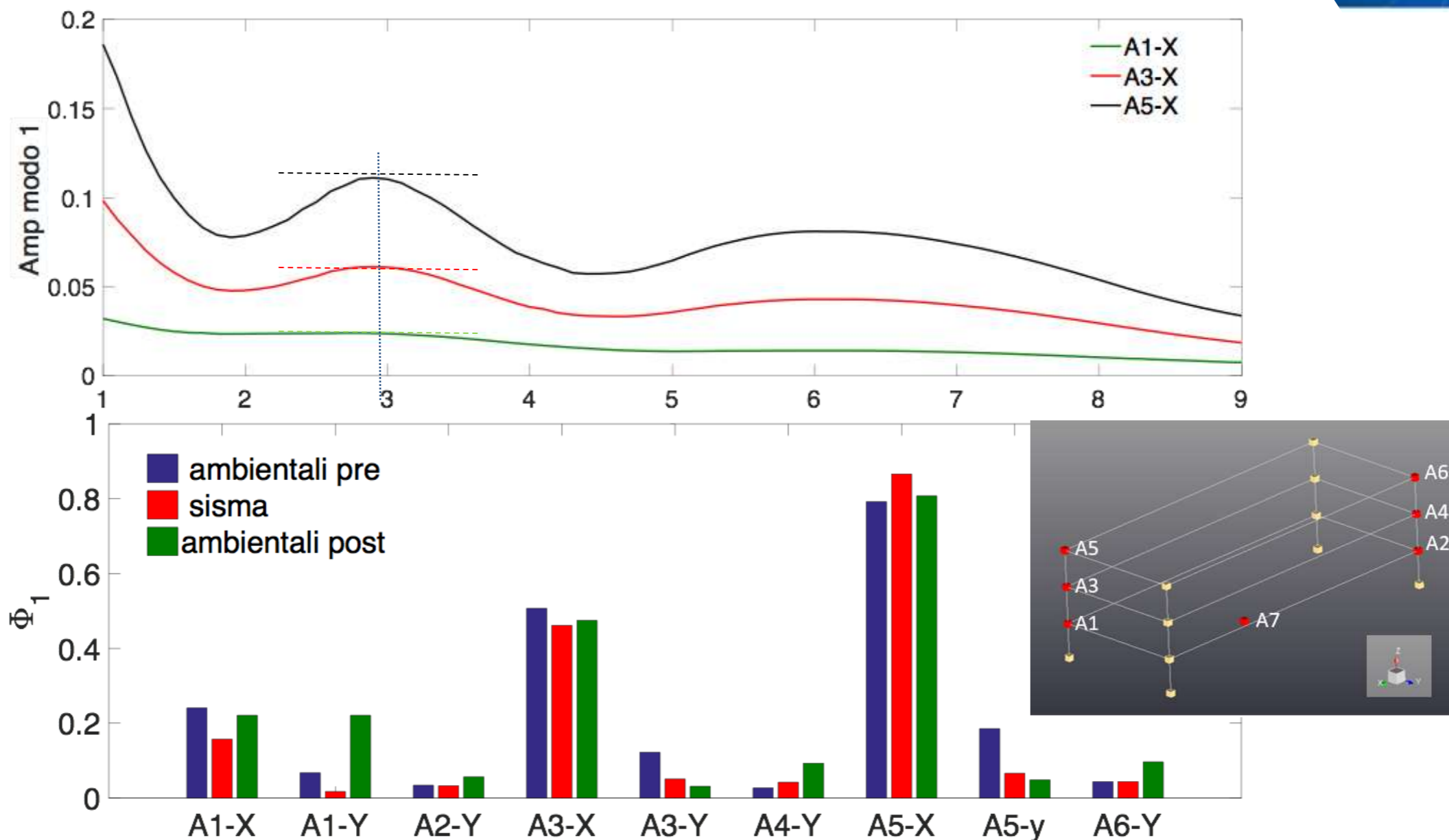
MAC(pre,sisma)=   0.96
MAC(pre, post)=   0.94
MAC(sisma,post)=0.94

Thank you
for the
attention

the **Seismic Observatory of Structures (OSS)** records the dynamic response of **155 public structures** (147 build-ings, 7 bridges and 1 dam):

> *schools   45%;*
> *hospitals   18%;*
> *town halls 20%;*
> *other   17%,*

with *reinforced concrete (65%)* or *masonry (35%)* structure.

Structures are chosen, that are representative of the public building stock and useful for emergency management.

R.C. building
Masonry building
Bridge
Dam

The OSS permanent network with complete instrumentation Updated April 2016

Structures are monitored in order to assess both their **health state** and possible **earthquake damage**.

Every floor (buildings) or span (bridges) or section (dam) is monitored with **4÷6 accelerometers**, cable- connected with a **central unit** that converts to digital and records &transmits by **ADSL** triggered data to the OSS **server** in Rome, where data are processed, **maxima and a** *damage index are computed, and (15-20' after the* quake) data&results are **shared through e-mail reports** and a dedicated **website**.

n →	**Force-balance accelerometer**
n ⇔	**Displacement sensor**
3, 1, 2 axes	**Triaxial f.-b. accelerometer**