ECGS & ESC/EAEE Joint Workshop 2015
EARTHQUAKE AND INDUCED MULTI-RISK EARLY WARNING AND RAPID RESPONSE
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An Attempt of Predicting the Macroseismic Intensity from Early Radiated Energy for On-site Earthquake Early Warning in Italy

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- Introduction

- A new EEW Relationship: integral of the squared velocity → Housner Intensity → Macroseismic Intensity (dataset Itaca)

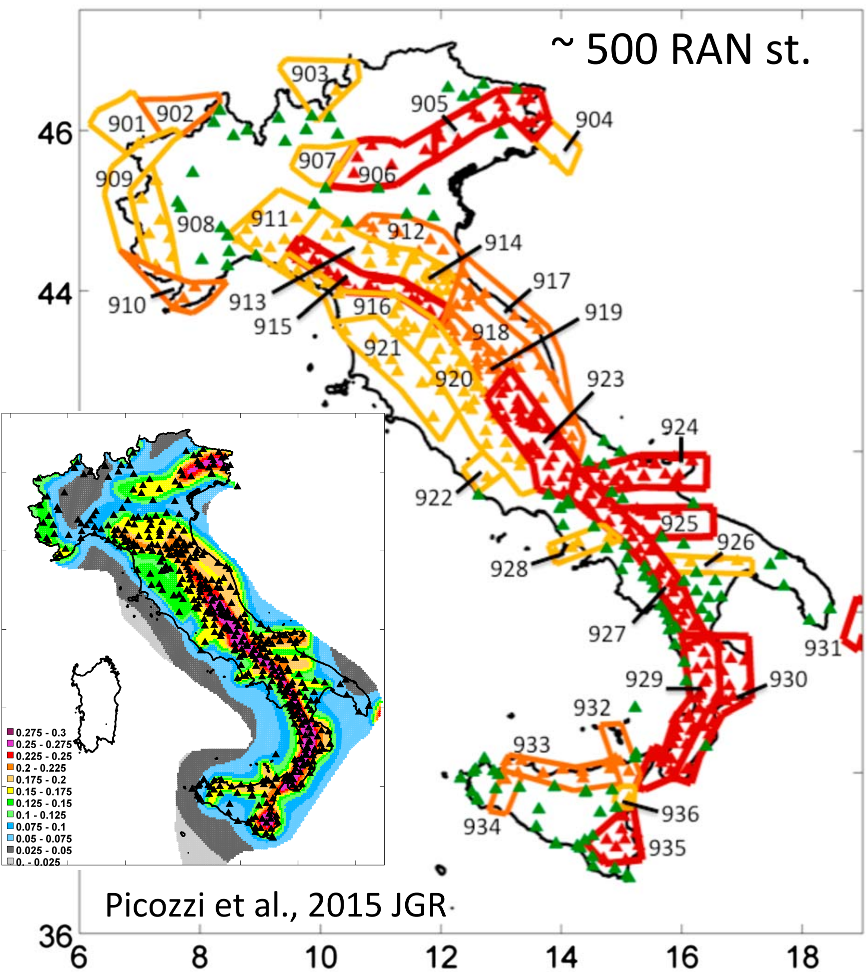
- application to OSS and ISMD datasets

- comparison of predicted and observed Intensity during the 29th May 2012 Emilia (M_W 5.9) Earthquake

- Conclusion

REGIONAL EEW APPROACH FOR ITALY

Feasibility study of a nation-wide Early Warning System: the application of the EEW software PRESTo on the Italian Strong Motion Network (RAN)



Picozzi et al., 2015 JGR

Distribution within seismic macro-zones (MZs)

Mmax ≥ 6.5 **mean int-st. D ~ 17.5 km**

6.5 > Mmax ≥ 6 **ID ~ 23 km**

6 > Mmax ≥ 5 **ID ~ 25 km**

5 > Mmax **ID ~ 34 km**

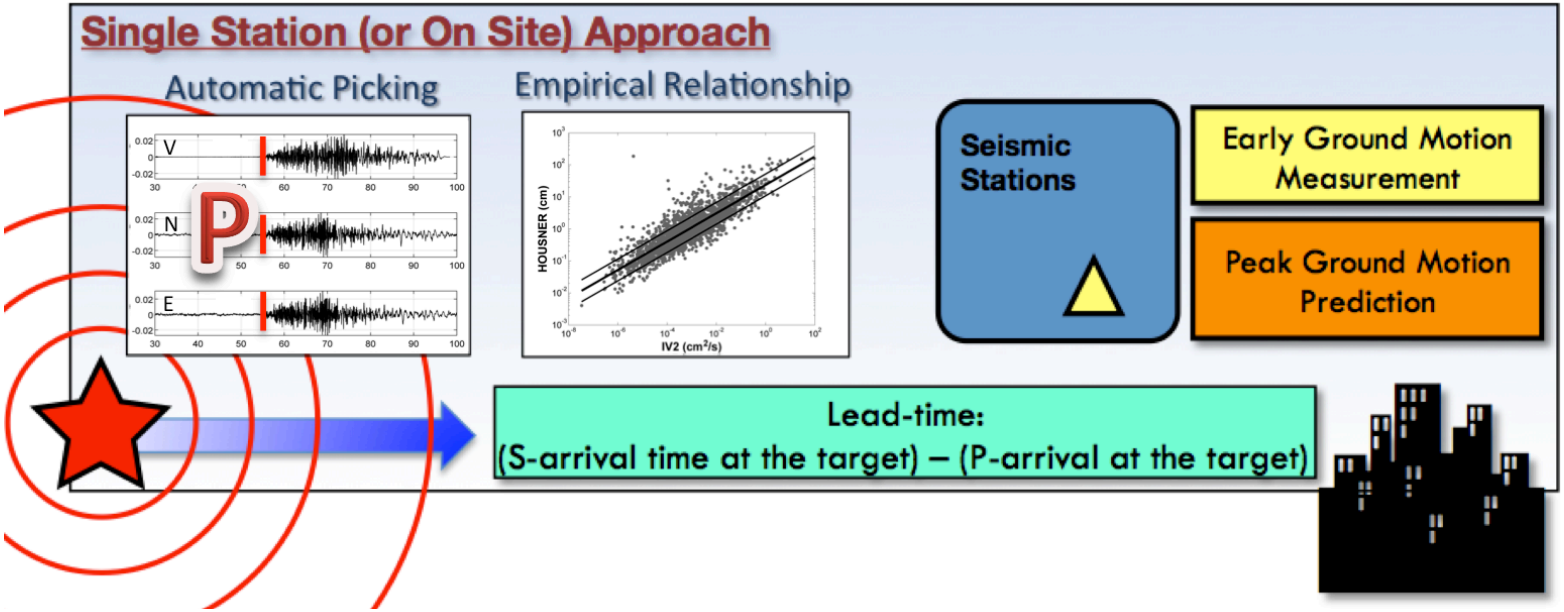
Table 2. Average of the EEWS Performance Parameters for the Four MZs and a Different Number of Triggered Stations[a]

Parameter	Number of Stations	I	II	III	IV
Time first alert (s)	3	3.7	4.5	5.0	11.4
Time first alert (s)	6	5.3	6.4	7.1	14.3
BZ radius (km)	3	23	25	26	42
BZ radius (km)	6	29	32	34	52

[a]Time is estimated off-line and does not include that needed for telemetry and computation.

SUCH DIMENSION OF BZ INDICATES THAT IN ITALY THE ONSITE METHOD SHOULD ALSO BE USED (INTEGRATED WITH THE REGIONAL SYSTEM)

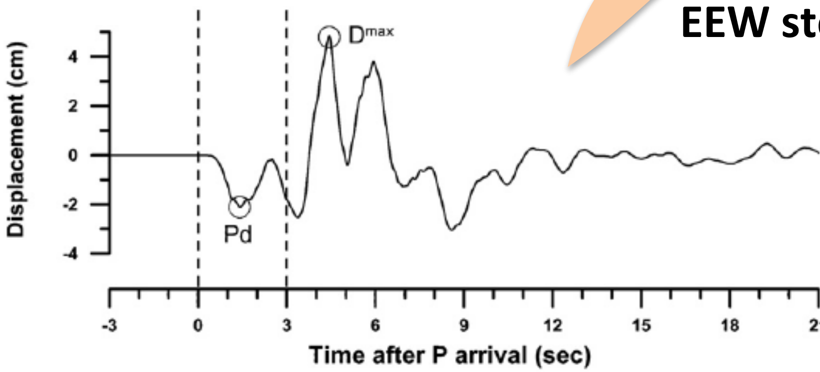
P-WAVE, THRESHOLD BASED, ONSITE EEW



- ✓ The P-wave onsite methods issue a threshold-based alert upon the analysis of initial P-wave motion at a single station or co-located array of sensors
- ✓ On-site systems can provide faster warning than regional systems to targets close to the epicenter (ideal for the protection of sites located in the vicinity of seismogenic zones)

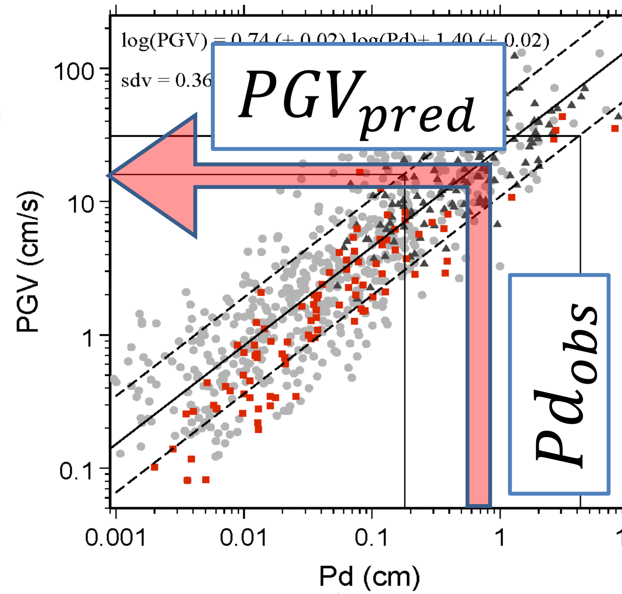
PROXIES FOR SHAKING INTENSITY ESTIMATION

*peak displacement **Pd***



after Shieh et al., SDEE (2010)

EEW step



RR step

I_{MM} by Faccioli & Cauzzi, 2006.

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)	<.03	.03-.29	.29-.93	.93-3.0	3.0-9.7	9.7-31	31-102	101-330	>330
PEAK VEL.(cm/s)	<.01	.01-.13	.13-.47	.47-1.7	1.7-6.1	6.1-22	22-78	78-282	>282
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

I_{MCS} by Faenza & Michelini, 2010.

$$I_{\mathrm{MCS}} = 5.11 \pm 0.07 + 2.35 \pm 0.09 \log PGV, \sigma = 0.26.$$

Are these peak parameters the best proxies we can rely on for the shaking intensity prediction?

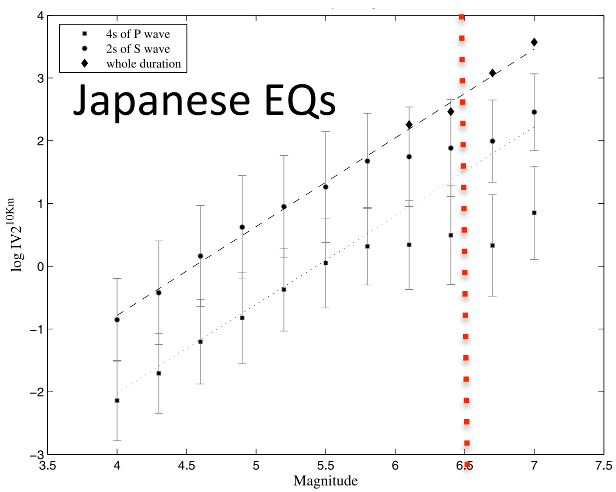
THE INTEGRAL OF THE SQUARED VELOCITY (IV2)

$$IV2_c = \int_{t_c}^{t_c+\Delta t_c} v_c^2(t)dt$$

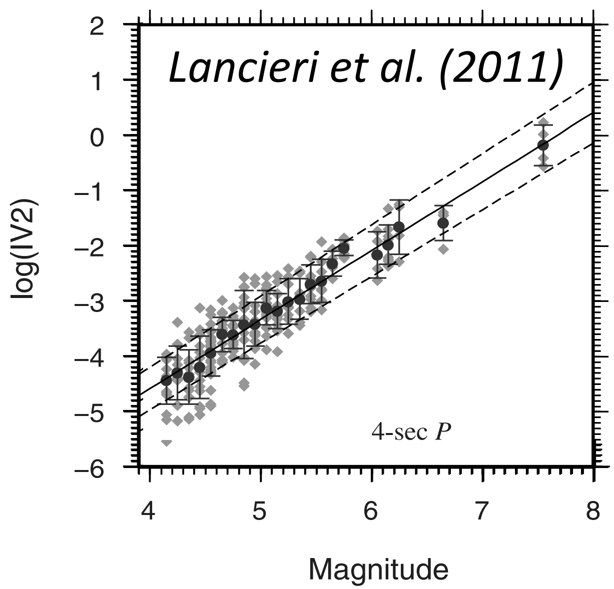
IV2 is a proxy of the energy radiated by the earthquake, and provides insights, although partial, into the physics of the earthquake rupture

***Regional EEW**: Proposed by Festa et al. (2008) for estimating the magnitude in real-time from P and S waves time windows*

Festa et al. (2008)



Saturation of the parameter for magnitudes around Mw 6.5



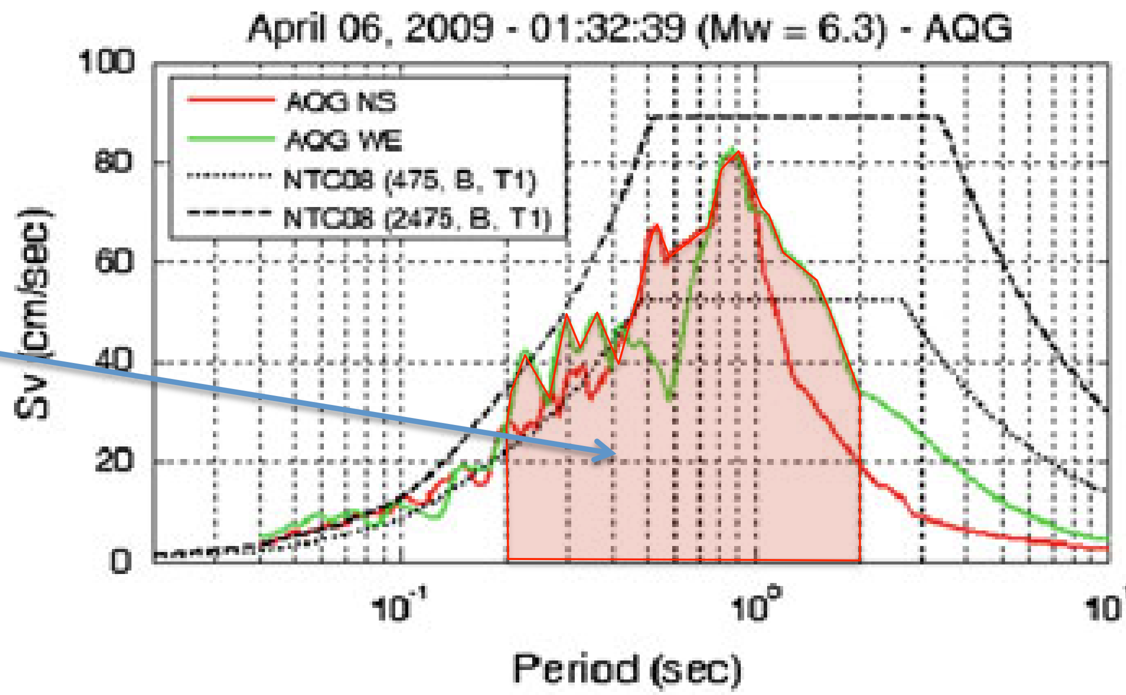
Aftershock sequence of the Tocopilla event of November 2007 (Mw 7.8) in northern Chile

No saturation up to Mw 7.8

HOUSNER INTENSITY

$$\mathrm{I_H} = \int_{0.2}^{2} \mathrm{PVS}(T, \xi)\,dT$$

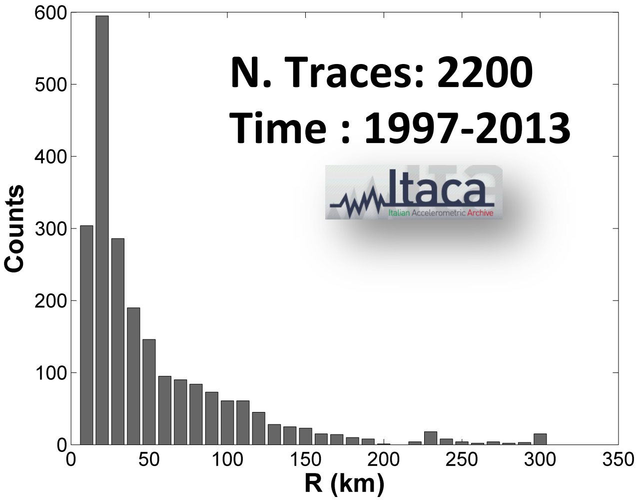
The Housner intensity is defined as the area under the pseudovelocity spectrum PSV(T, ξ) of the seismogram (Housner, 1952)

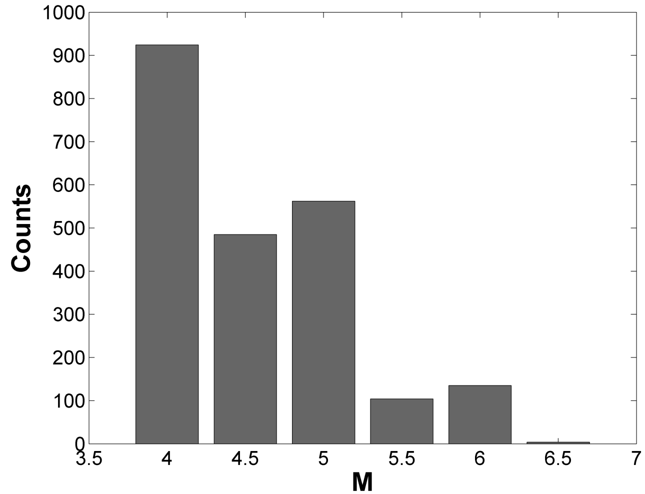


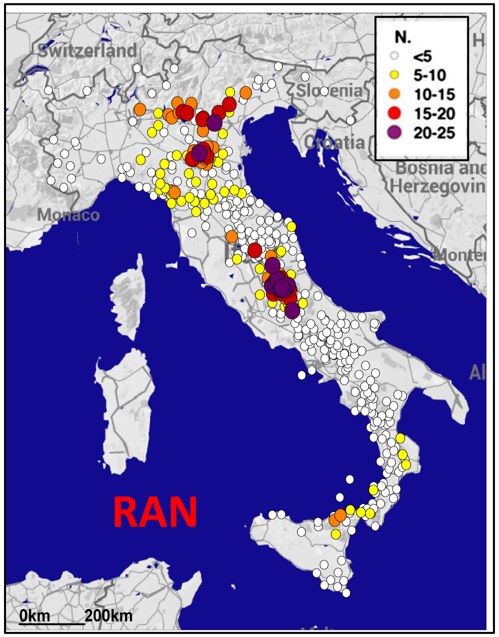
The Housner Intensity is better correlated than PGV, PGA and Arias Intensity to the severity of earthquake ground motion and with building structural damage (Masi et al., 2010).

DATA SETS

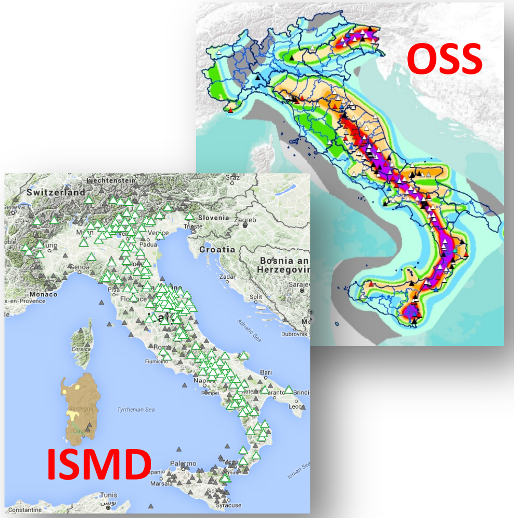
CALIBRATION DATA-SET → RAN traces

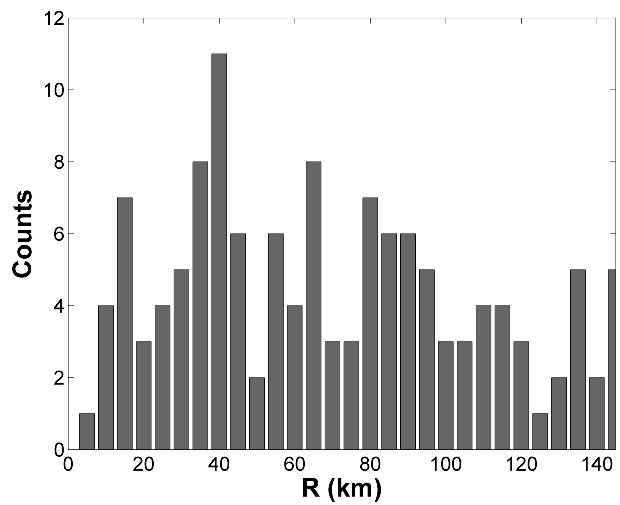


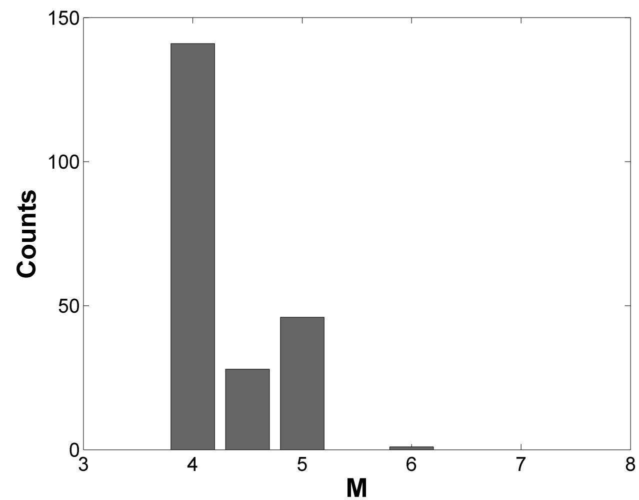




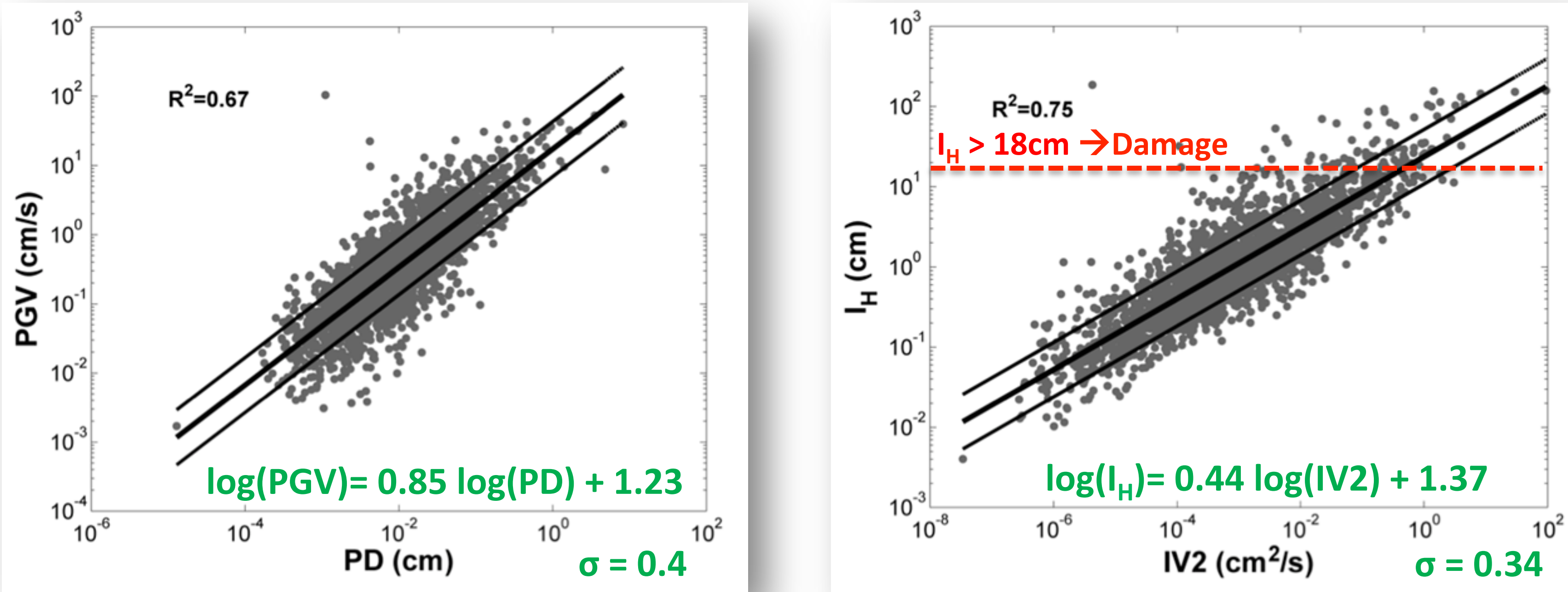
TESTING DATA-SETS → OSS (DPC- 30 tr. 2009-2014) + ISMD (INGV- 190 tr. 2014-2015)



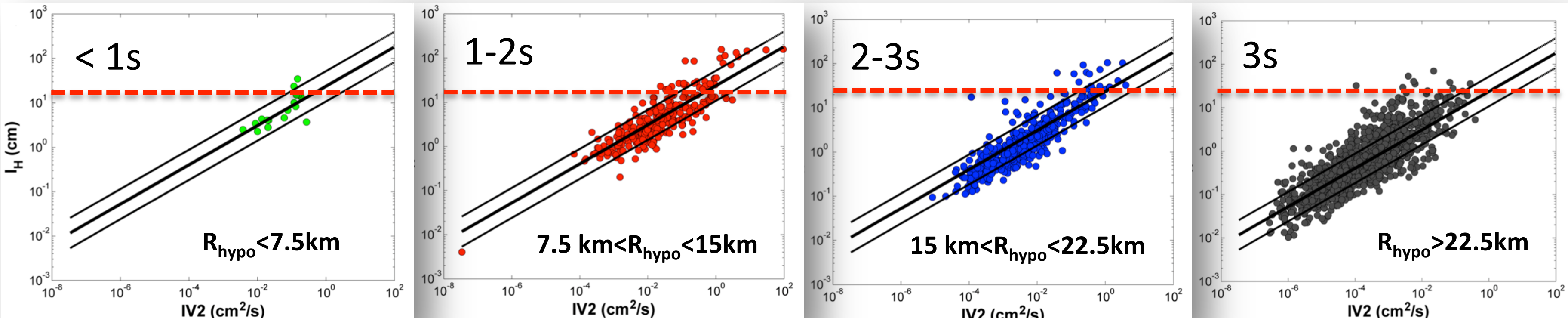




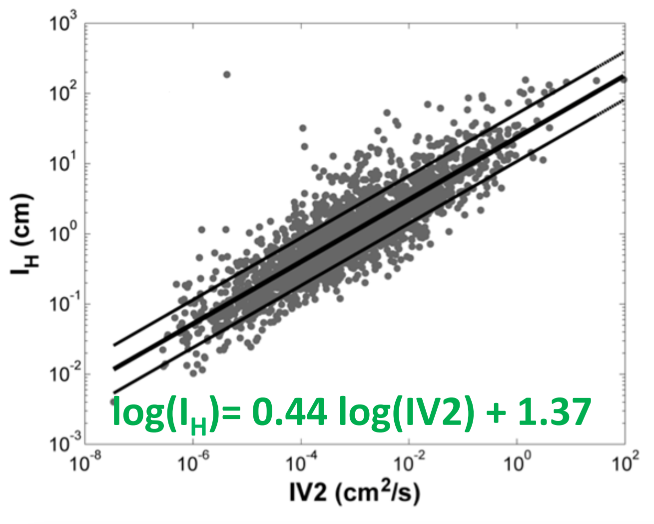
Empirical relationships for PD and IV2



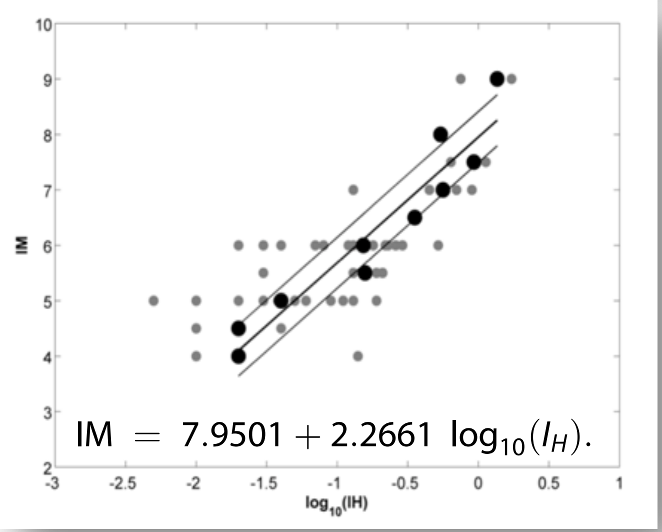
Distance Effect on IH-IV2 Relationship

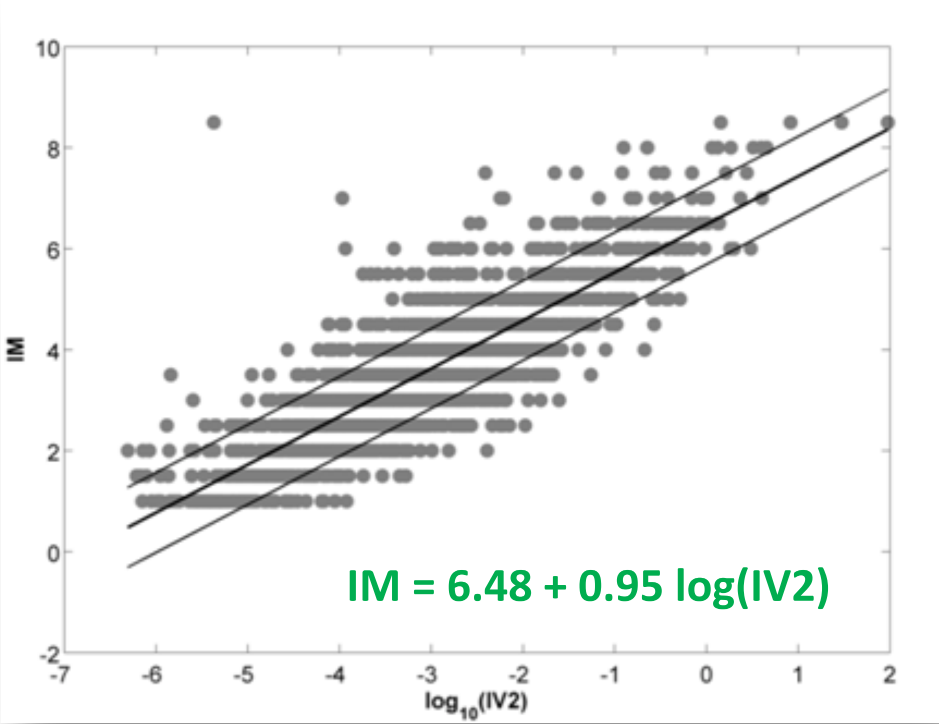


THE METHODOLOGY: IM BY IV2



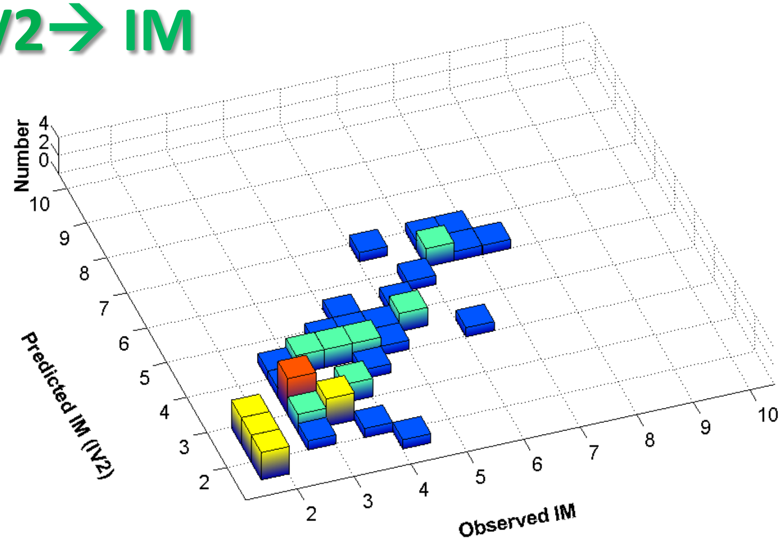
We exploited the relations existing between IV2 and IH and between IH and IM, in order to predict IM directly from IV2 estimates



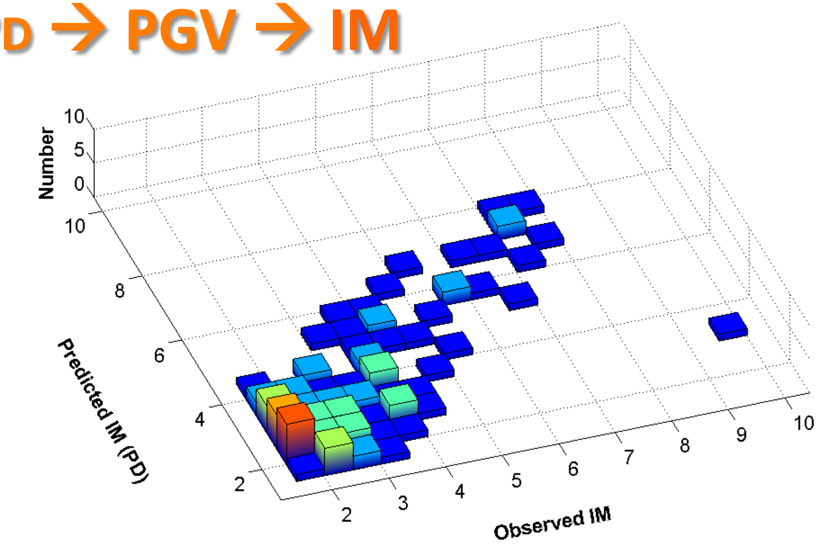


PREDICTED VS OBSERVED IM (OSS & ISMD DATA)

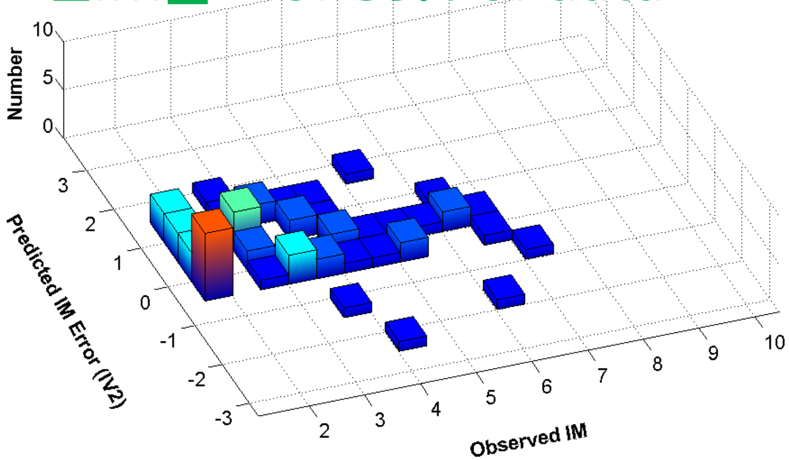
IV2→ IM



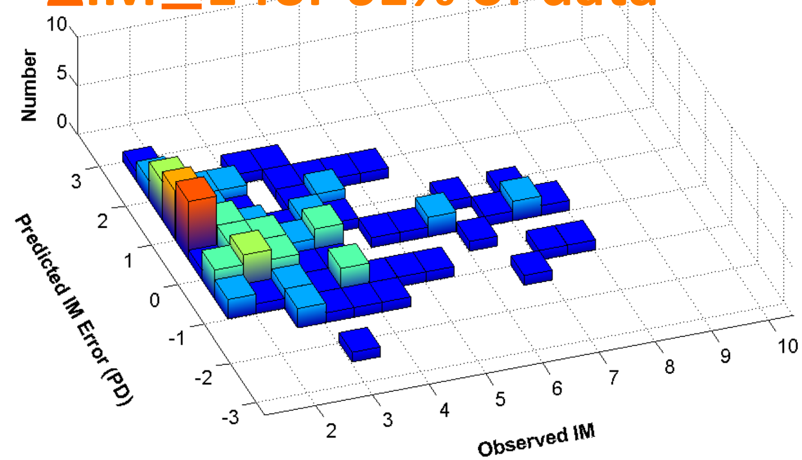
PD → PGV → IM



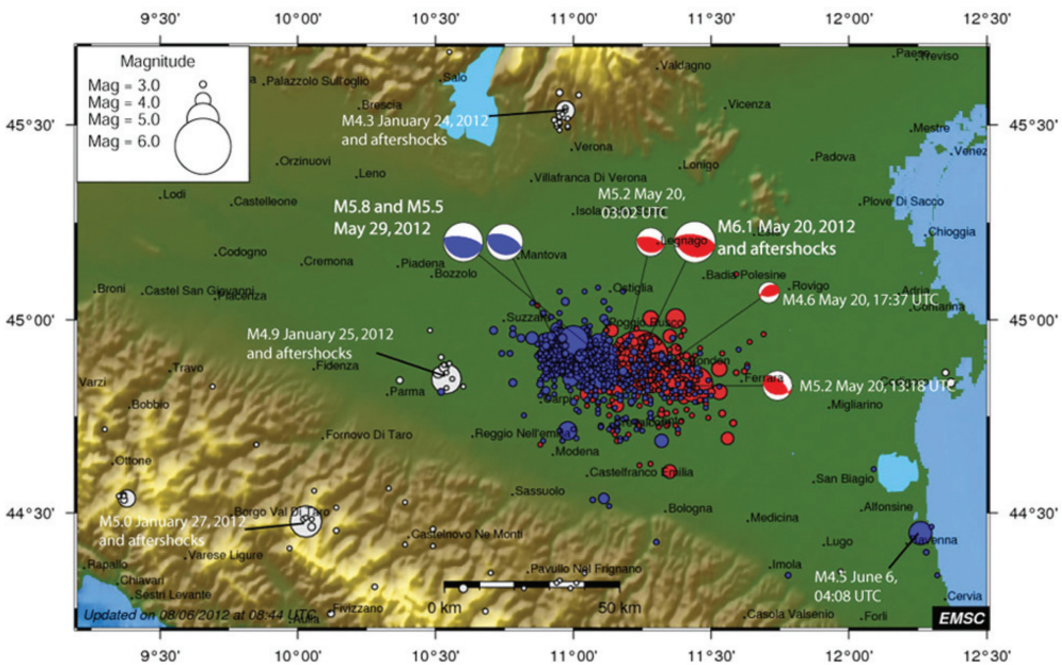
ΔIM≤1 for 85% of data



ΔIM≤1 for 61% of data



APPLICATION TO THE MAY 29TH 2012 EMILIA M_W 5.9 EARTHQUAKE



Galli et al., 2012

RAN Latitude	RAN Longitude	Hypocentral Distance (km)	Distance RAN Versus Observed IM (km)
44.9320	10.9120	19.4	0.60
44.8864	11.0728	11.0	0.54
44.8380	11.1430	11.3	0.44
44.8297	11.2867	19.0	0.51
44.7234	11.2867	23.6	0.30
44.7157	11.1428	18.8	0.76
44.7910	11.3904	27.0	0.24
44.8860	11.4180	28.4	0.22
45.0250	11.3110	28.2	0.71
44.7823	10.8703	21.3	0.18
44.7190	11.5340	39.6	0.16
44.8419	10.7306	29.9	0.31
44.9340	11.2350	18.1	0.47
45.0100	11.2958	26. 3	0.62
44.7668	11.3508	25.1	0.99
44.7594	10.9276	19.1	0.55

Source	Length	Width	Top depth	Strike	Dip	Rake	Slip max
20/5	35 km	20 km	500 m	105°	50°	85°	>68 cm
29/5	32 km	20 km	1000. m	95°	55°	90°	72 cm

Carydis et al., 2012

We have limited the comparison to 16 sites with station to surveyed site distances less than 1 km

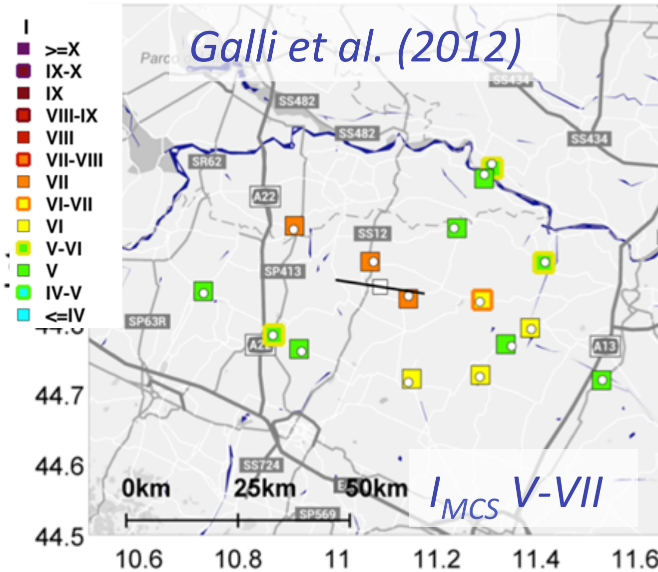
THE MAY 29TH 2012 EMILIA M_W 5.9 EARTHQUAKE

Galli et al. (2012)

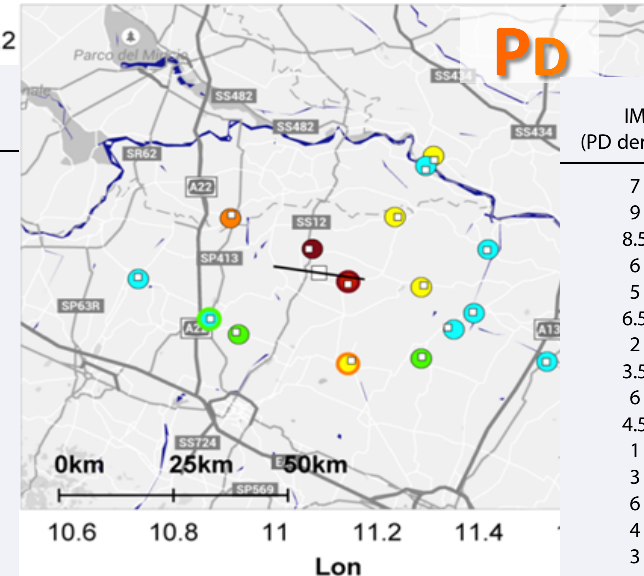
... We re-started the macroseismic survey on the morning of May 29, 2012, visiting again the villages hit by the May 20, 2012, event, for up to 190 localities belonging to 87 municipalities.

... We observed an increase of 1-2 MCS degrees in some villages in the western part of the area

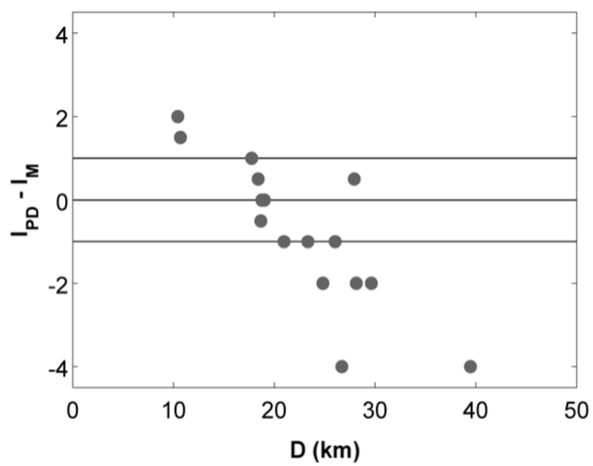
... In the other localities generally west of Mirandola, the intensity grew by <1 MCS degree

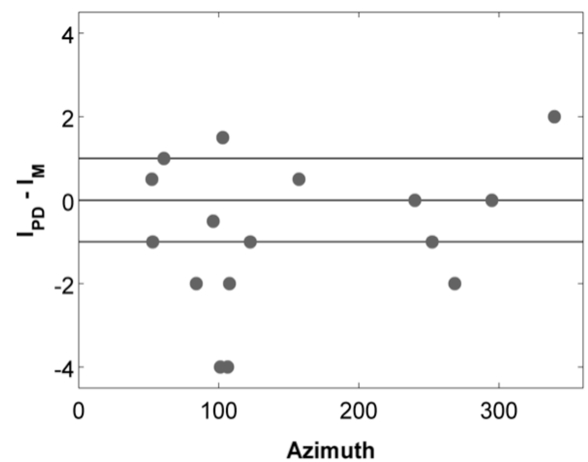


Observed IM
7.0
7.0
7.0
6.5
6.0
6.0
6.0
5.5
5.5
5.5
5.0
5.0
5.0
5.0
5.0
5.0

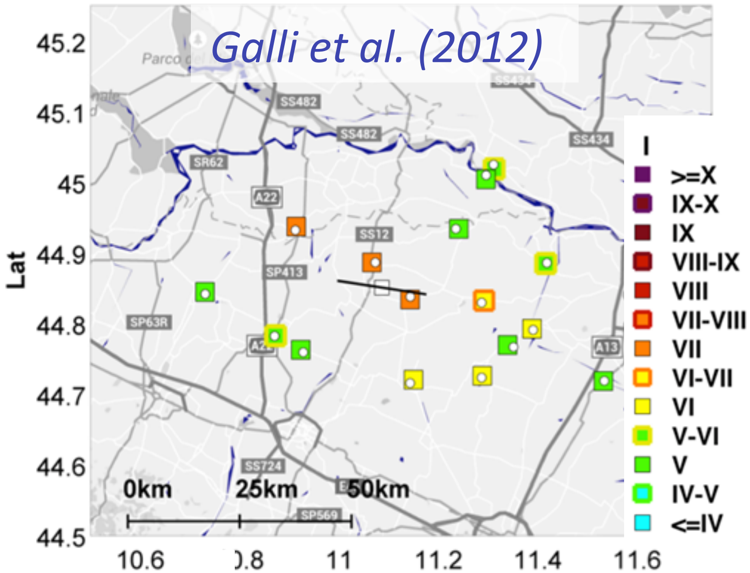


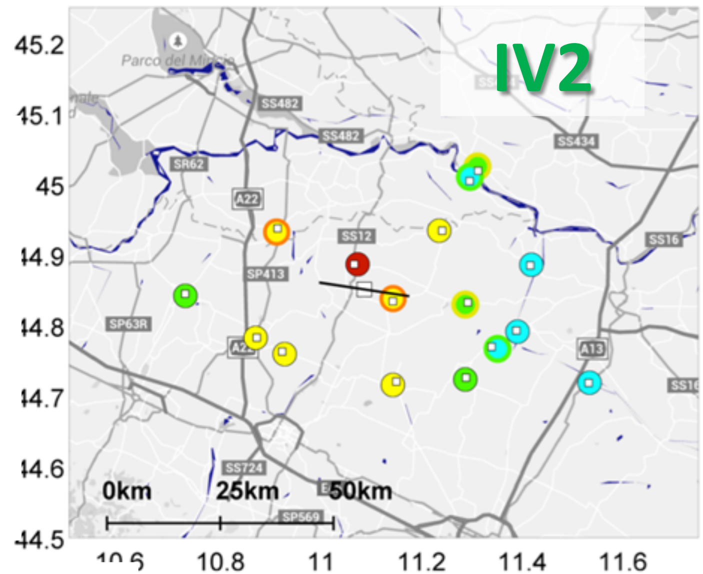
IM (PD derived)
7
9
8.5
6
5
6.5
2
3.5
6
4.5
1
3
6
4
3
5



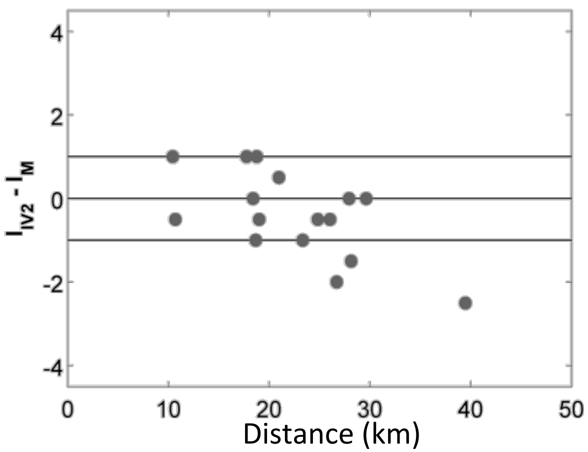


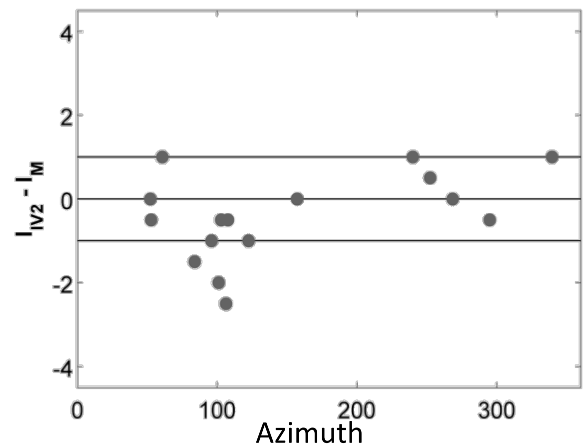
THE MAY 29TH 2012 EMILIA M_W 5.9 EARTHQUAKE





IM (IV2 derived)	Observed IM
6.5	7.0
8	7.0
6.5	7.0
5.5	6.5
5	6.0
6	6.0
4	6.0
4	5.5
5.5	5.5
6	5.5
2.5	5.0
5	5.0
6	5.0
4.5	5.0
4.5	5.0
6	5.0

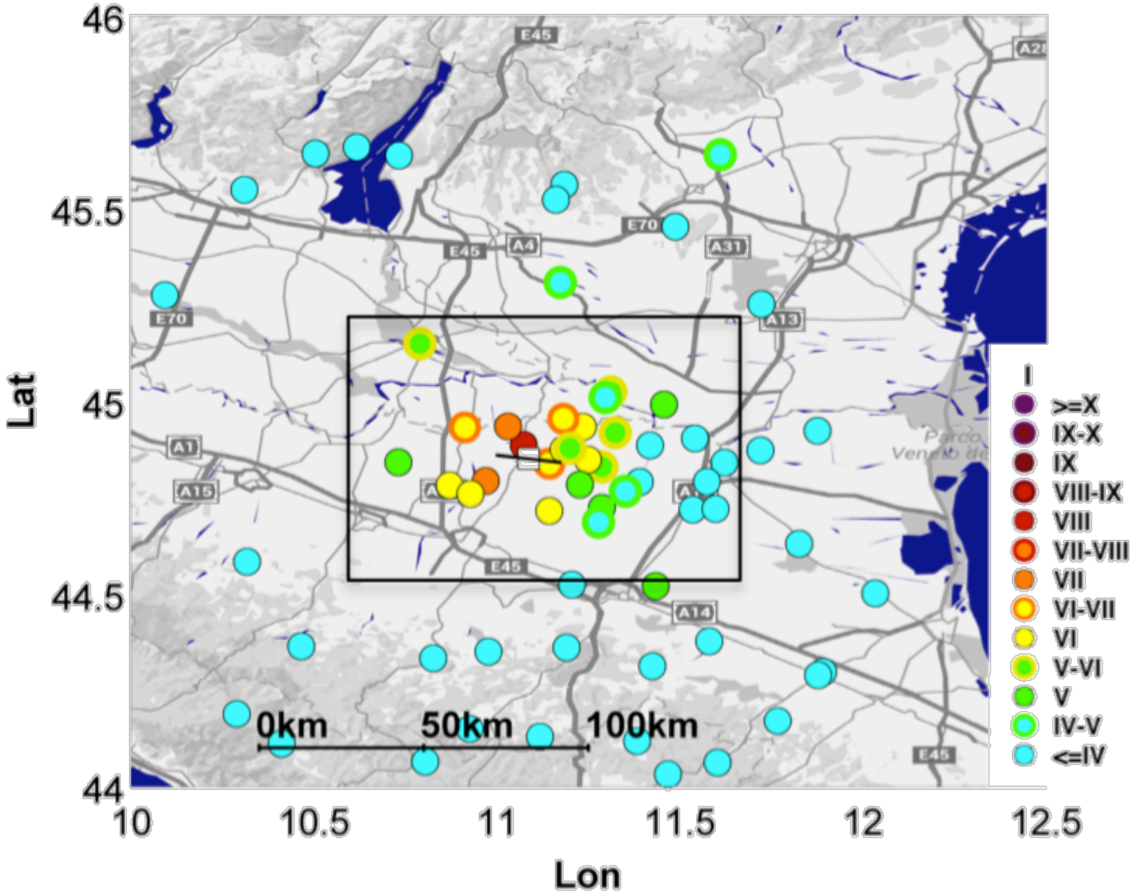




IV2 → THE RESIDUALS ARE MOSTLY WITHIN ±1 INTENSITY UNITS, WITH THE EXCEPTION OF THREE STATIONS IN THE DISTANCE RANGE 25 TO 40 KM, AND AZIMUTH EQUAL TO ABOUT N100°E.

THE MAY 29TH 2012 EMILIA M_W 5.9 EARTHQUAKE

IM_{EEW} map for the 29 May 2012 Emilia earthquake, considering stations within 100 km from the epicenter



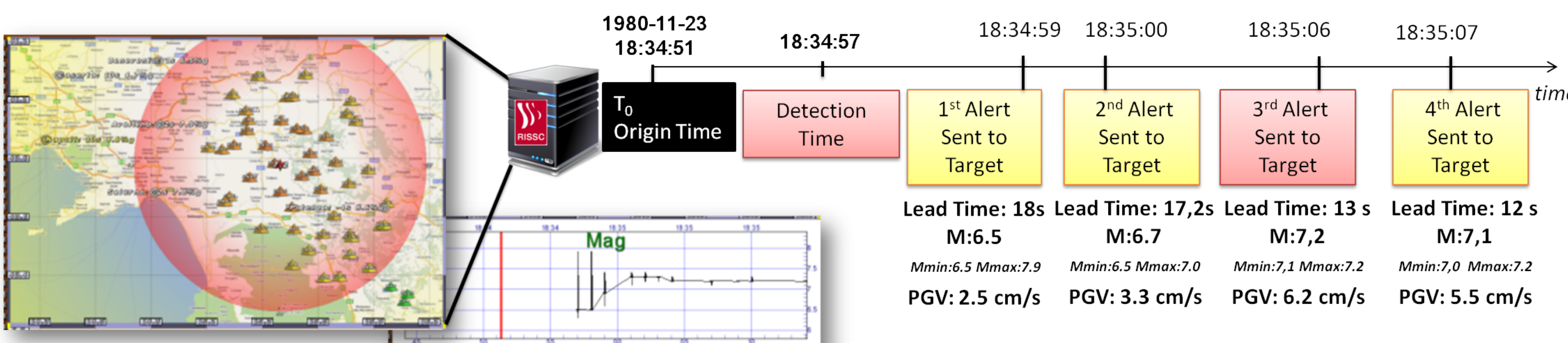
DRILL @ SCHOOL: playback of the *simulated* M_S6.9, 1980 Irpinia earthquake

EEW drill at MAJI: some facts

Time needed for going under the desk ≈ **<u>3-5 s</u>**

Alert duration ≈ 150 s

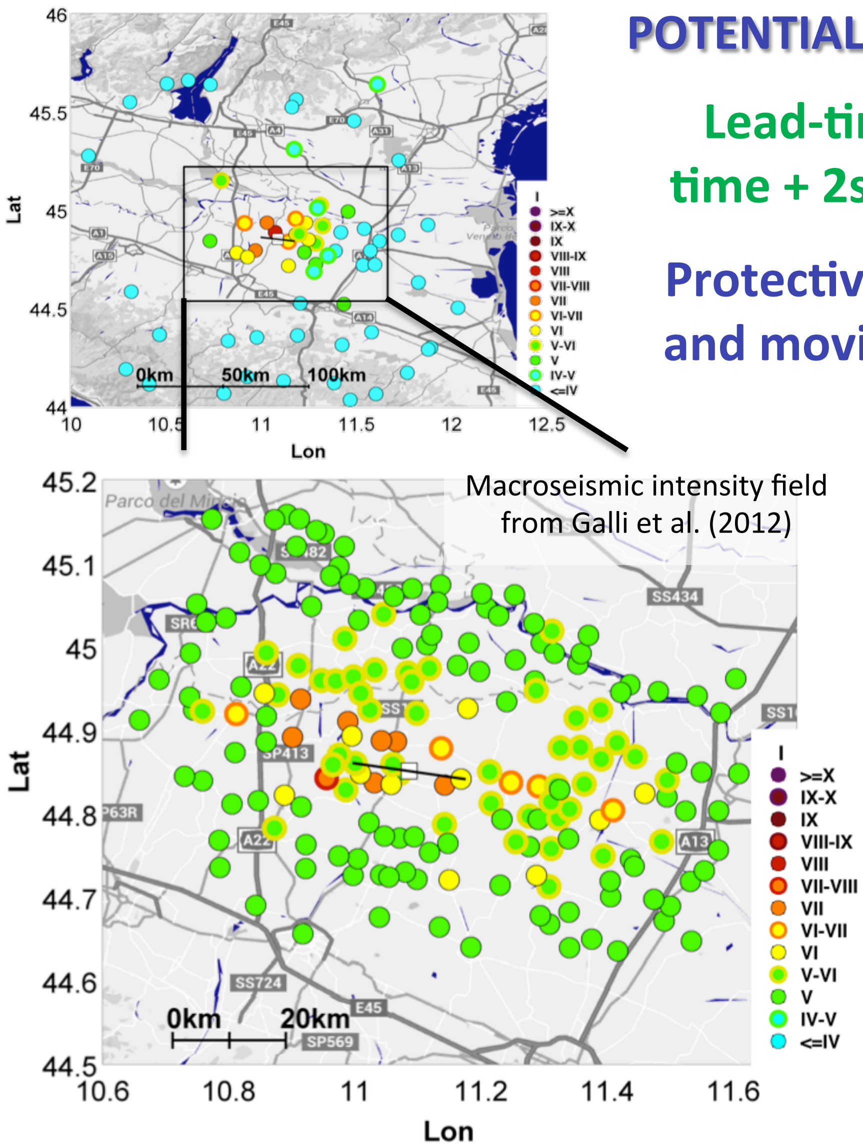
Alert level: moderate predicted PGV ≈ 5.5 cm that corresponds to IMM of VI (strong perceived shaking/ light potential damage)



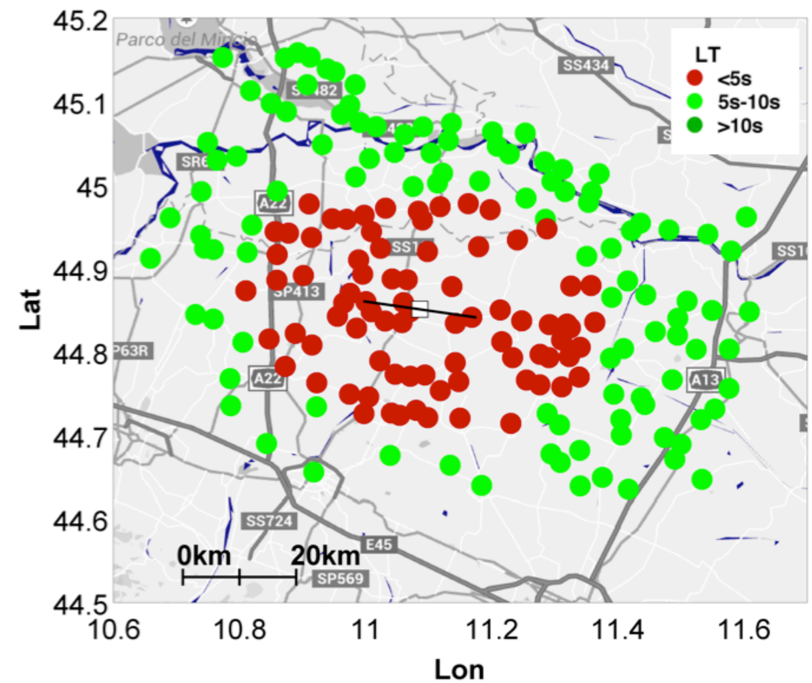
POTENTIAL BENEFIT OF THE EEW

Lead-time = arrival time PGV - (arrival P wave time + 2s P window time + 1s computation time)

Protective actions, we considered "duck and cover" and moving away from windows or equipment (5 s)



Macroseismic intensity field from Galli et al. (2012)



190,000 inhabitants potentially warned/informed

Conclusion

- The relationship between IV2 and I_H has the potential to become a key relationship in the design of on-site EEWS (real-time prediction of damage/undamaged)

- For events having magnitudes around Mw 6, which in Italy occur roughly every 10 to 20 years and are responsible for considerable damage, even the availability of only 1s of P wave signal would provide I_H estimates useful for EEW purpose

- IV2 is a good proxy for the prediction of the IM in EEW applications (OSS-ISMD dataset, 85% of the cases the IM predicted by IV2 were within ±1 unit of the reference IM)

Thanks for your attention!

Table 2. Comparison of IM Predicted and Observed by *Galli et al*. [2012] After the M_W 6, 29 May 2012 Emilia Earthquake for RAN Stations and Localities Within 1 km of Distance[a]

RAN Latitude	RAN Longitude	Hypocentral Distance (km)	IM (IV2 derived)	IM (PD derived)	Latitude-Observed IM	Longitude-Observed IM	Observed IM	Distance RAN Versus Observed IM (km)
44.9320	10.9120	19.4	6.5	7	44.9372	10.9139	7.0	0.60
44.8864	11.0728	11.0	8	9	44.8864	11.0660	7.0	0.54
44.8380	11.1430	11.3	6.5	8.5	44.8341	11.1425	7.0	0.44
44.8297	11.2867	19.0	5.5	6	44.8326	11.2917	6.5	0.51
44.7234	11.2867	23.6	5	5	44.7259	11.2880	6.0	0.30
44.7157	11.1428	18.8	6	6.5	44.7205	11.1497	6.0	0.76
44.7910	11.3904	27.0	4	2	44.7926	11.3883	6.0	0.24
44.8860	11.4180	28.4	4	3.5	44.8849	11.4157	5.5	0.22
45.0250	11.3110	28.2	5.5	6	45.0187	11.3122	5.5	0.71
44.7823	10.8703	21.3	6	4.5	44.7825	10.8724	5.5	0.18
44.7190	11.5340	39.6	2.5	1	44.7187	11.5320	5.0	0.16
44.8419	10.7306	29.9	5	3	44.8447	10.7303	5.0	0.31
44.9340	11.2350	18.1	6	6	44.9341	11.2409	5.0	0.47
45.0100	11.2958	26. 3	4.5	4	45.0044	11.2954	5.0	0.62
44.7668	11.3508	25.1	4.5	3	44.7697	11.3389	5.0	0.99
44.7594	10.9276	19.1	6	5	44.7628	10.9226	5.0	0.55

[a]See Figure 7 and section 4.4 for details.