EARLY WARNING SYSTEMS FOR DEBRIS FLOWS: STATE OF THE ART AND CHALLENGES
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SETTIMANA NAZIONALE DELLA PROTEZIONE CIVILE
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LESSONS FROM SEISMOLOGY: EARLY WARNING SYSTEMS FOR EARTHQUAKES

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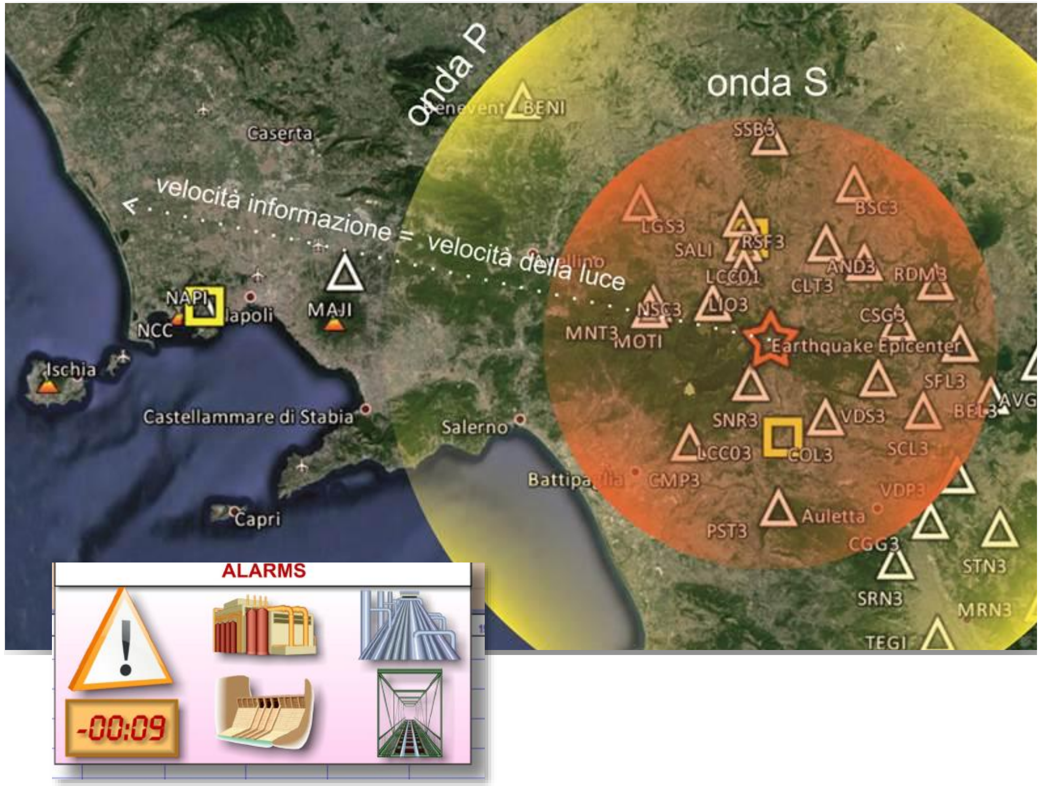


With the contribution of:
S. Colombelli, L. Elia, G. Festa, A.G. Iaccarino, A. Zollo and the RISSCLab team

THE PIONEERING IDEA OF EW BY DR.COOPER

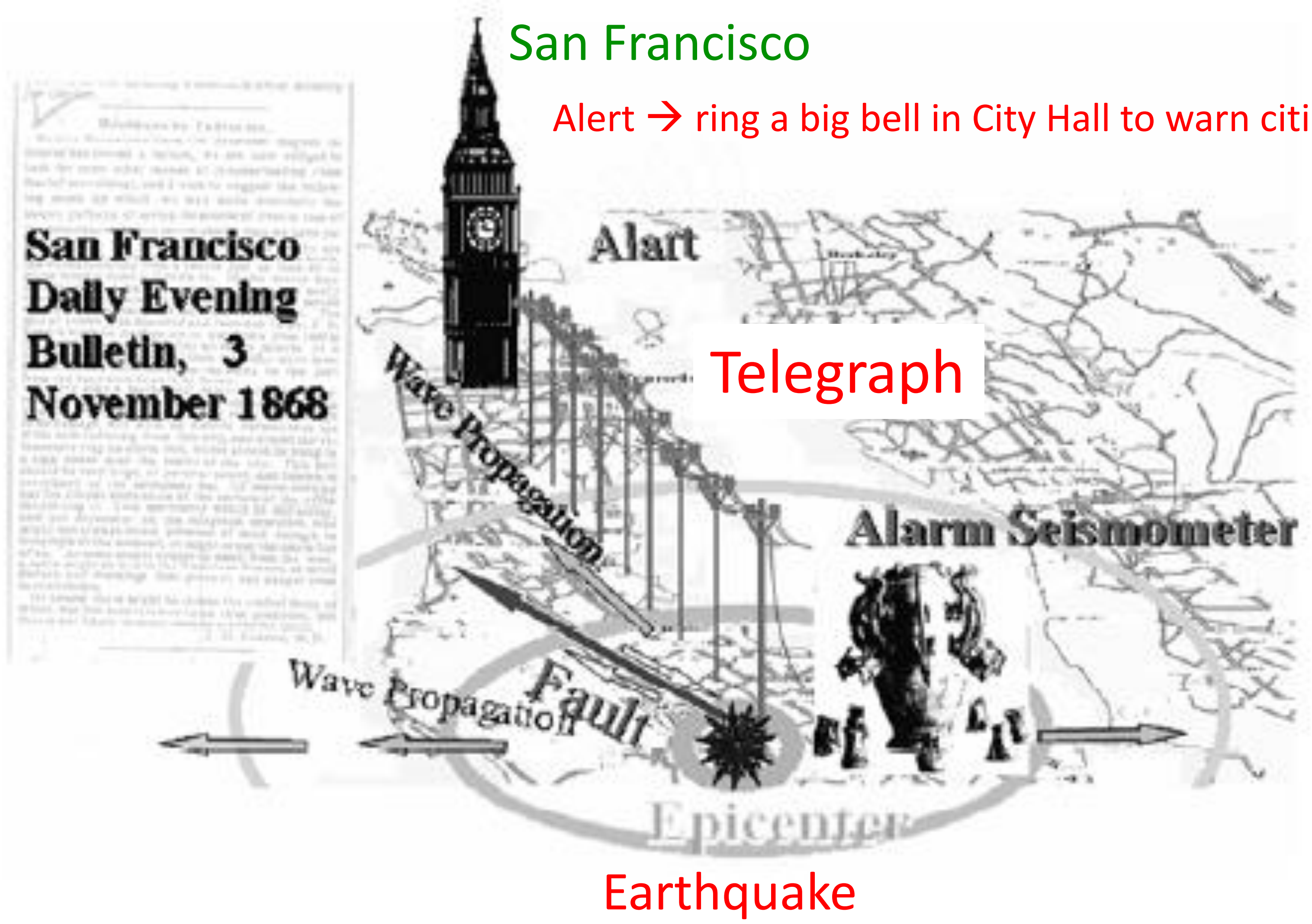
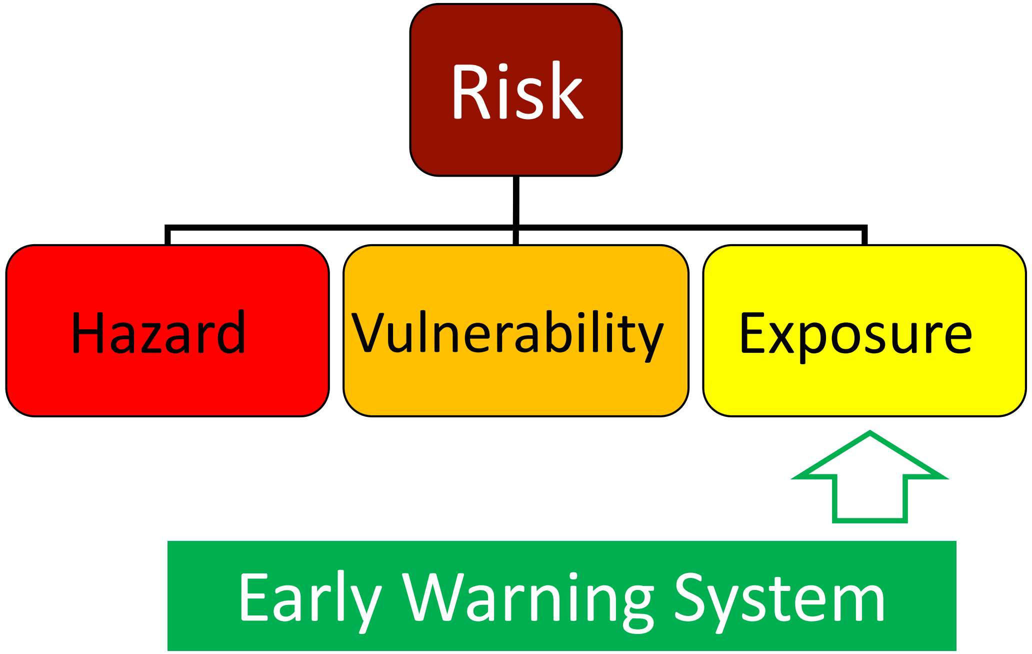


Fig. 13.1 The concept of the first detection system by Dr. Cooper.

Unfortunately, Cooper's scheme was never implemented.

Seismic Risk Mitigation



Seismic Risk Mitigation

Risk

Hazard | Vulnerability | Exposure

Earthquake Early Warning (EEW) System

Broadcast Alert

Automatic Low-Cost Safety Systems

Safety Majors Sensitive Env.

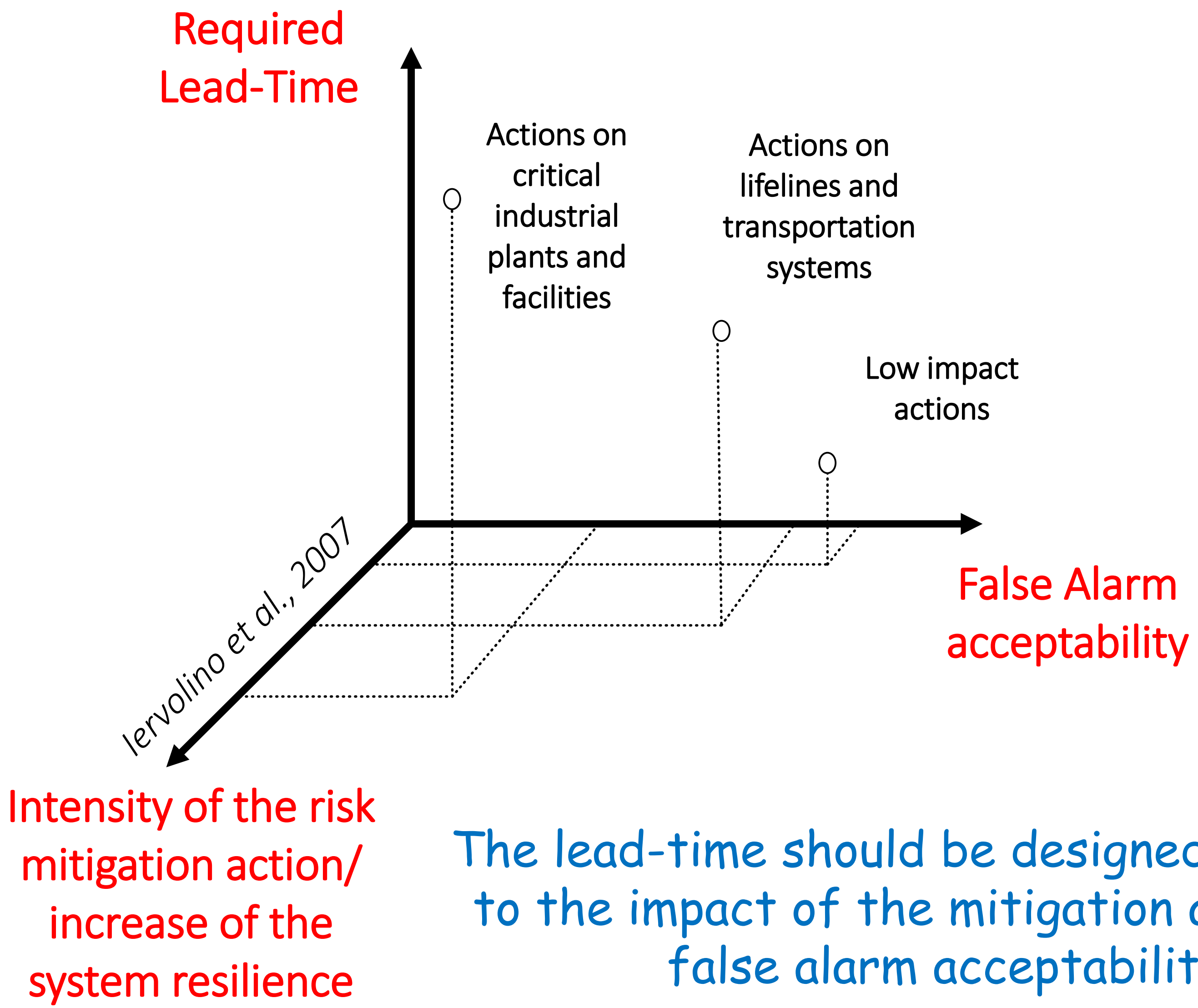
High Risk Plant/Structure

School Alert

Making Safe men at work

Decision Support System for Transport Infrastructures

WHICH ALERT THRESHOLD?



COST-BENEFIT ANALYSIS

LEAD-TIMES VS. MITIGATION ACTIONS

Three classes of actions:

1/ low impact: stop elevators, children under the desk,..

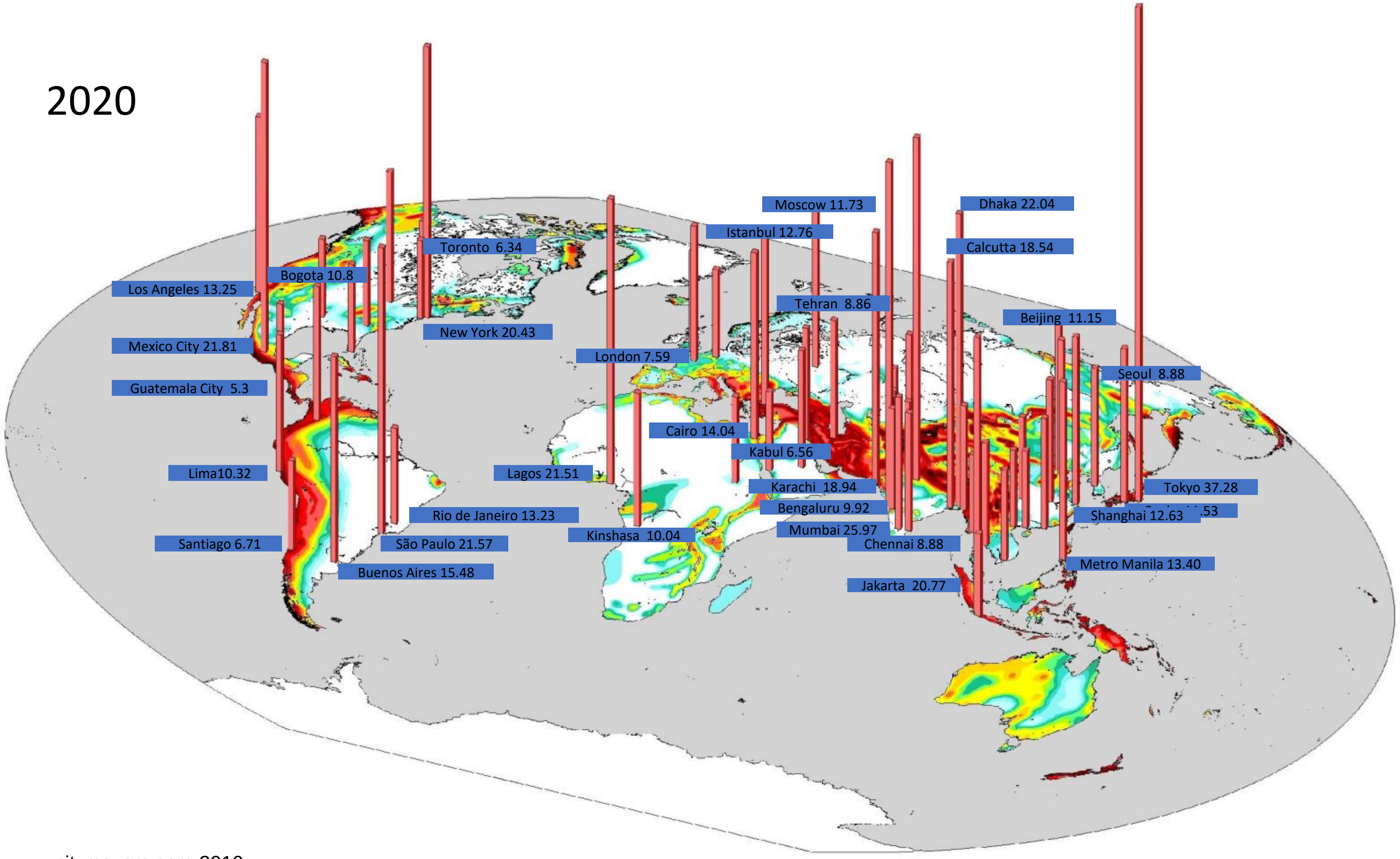
2/ medium impact: actions on lifelines (shut-off gas/electric supply, stop or slow down train,

3/high impact: shut-off large industrial plants, as nuclear, electro-thermal, chemical

The lead-time should be designed according to the impact of the mitigation action and false alarm acceptability

Megacities > 5 milion

7 in the 1950 → 2015: 60

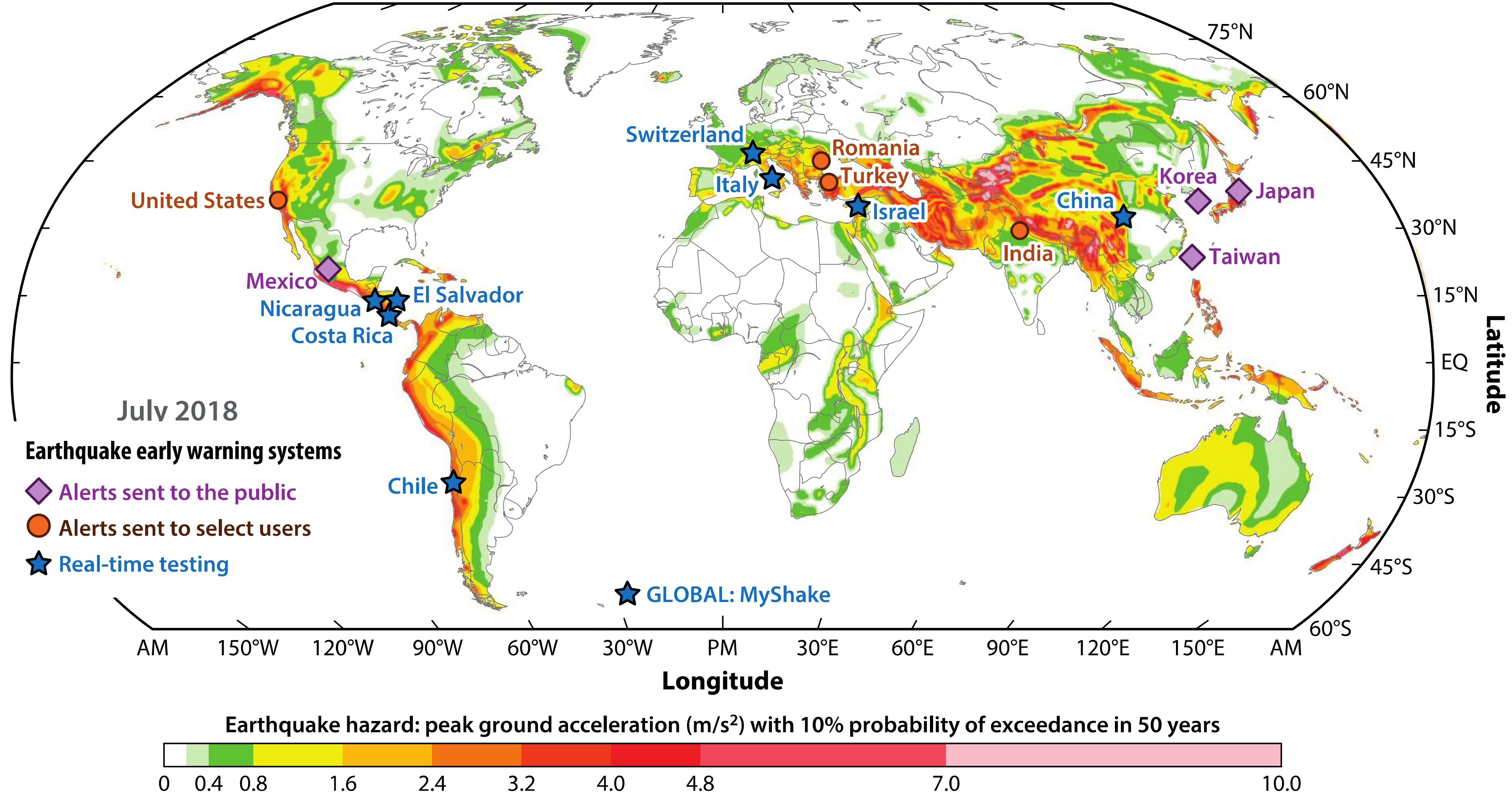


www. citymayors.com 2010

The Urban Explosion

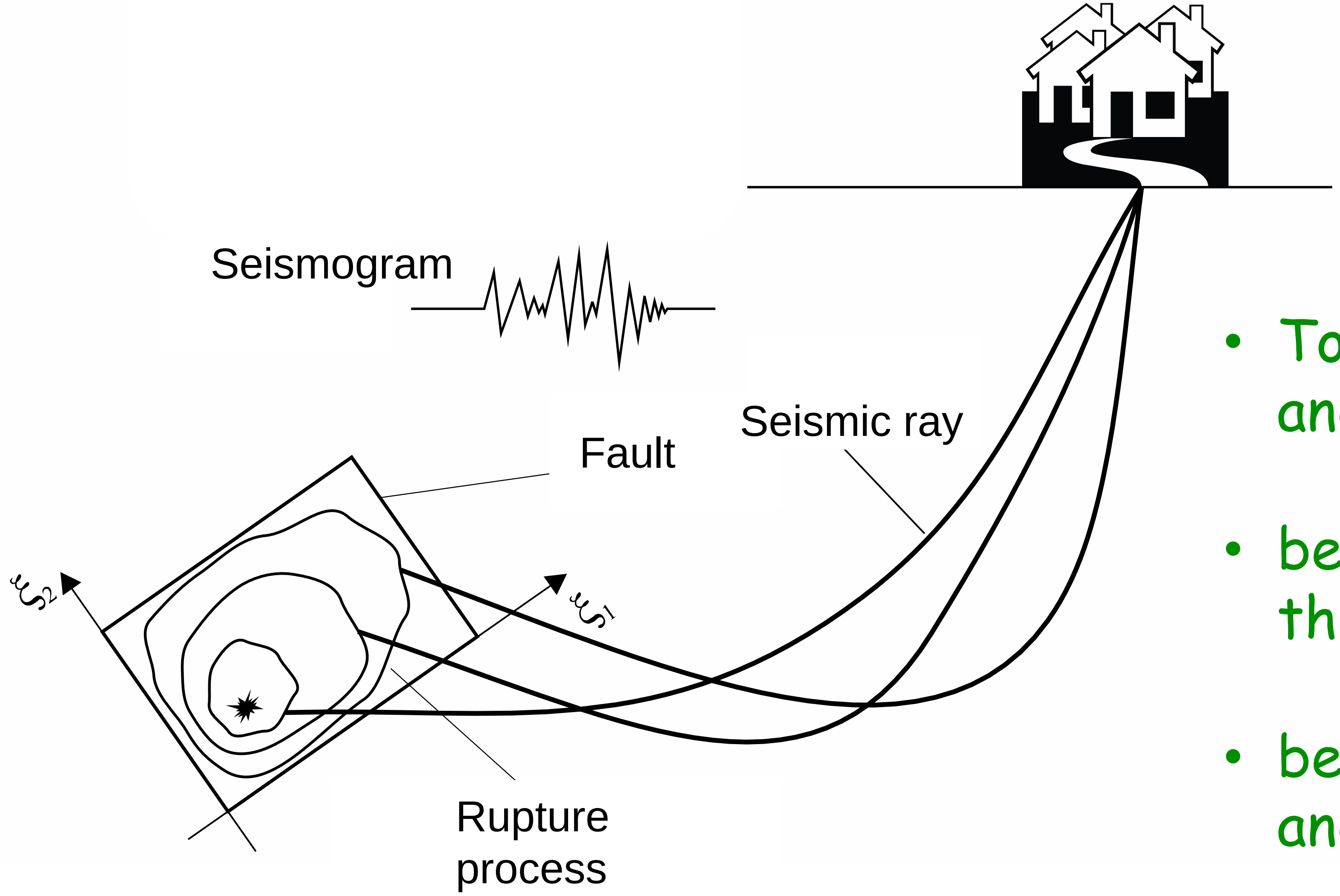
It is followed by a dramatic increase of seismic risk!

Worldwide Early Warning Systems



from Allen & Melgar, 2019

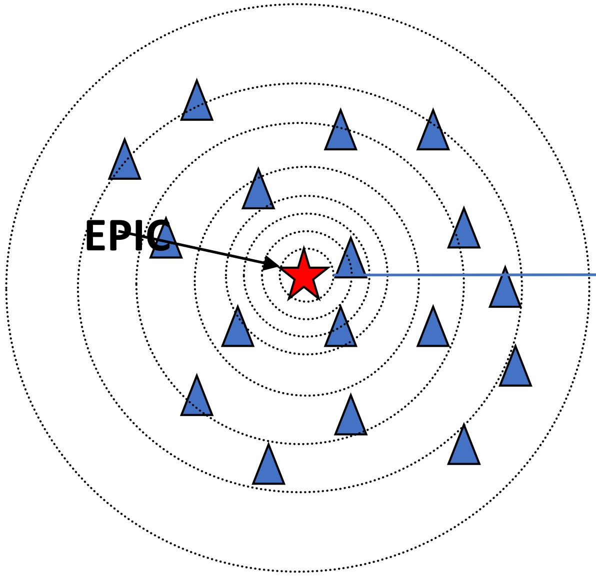
EEW is the delivery of ground shaking alerts or warnings.



What truly matters?

- To predict the ground shaking and/or damage at a target site
- be fast to alert end-users with the maximum lead-time possible
- be accurate to reduce the false and missed alerts

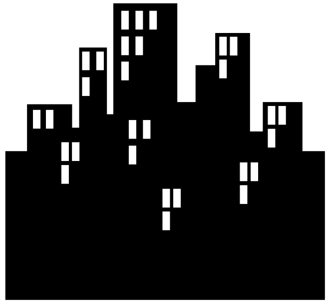
Regional EEW



Light speed ~ $3x10^5$ km/sec

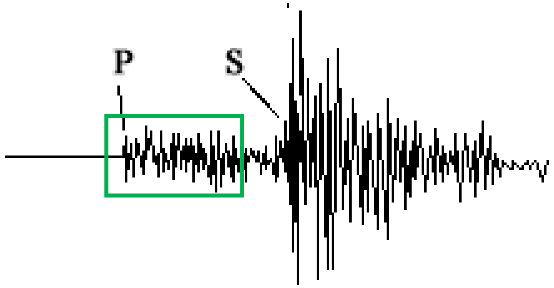
S-wave velocity ~3.5 km/sec

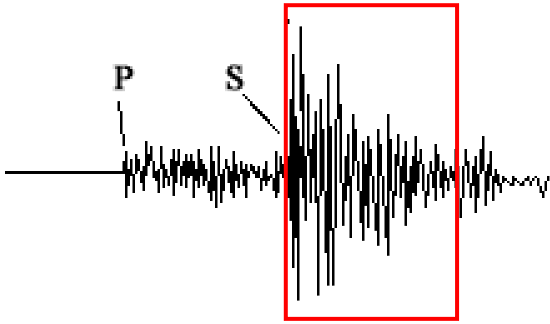
TARGET

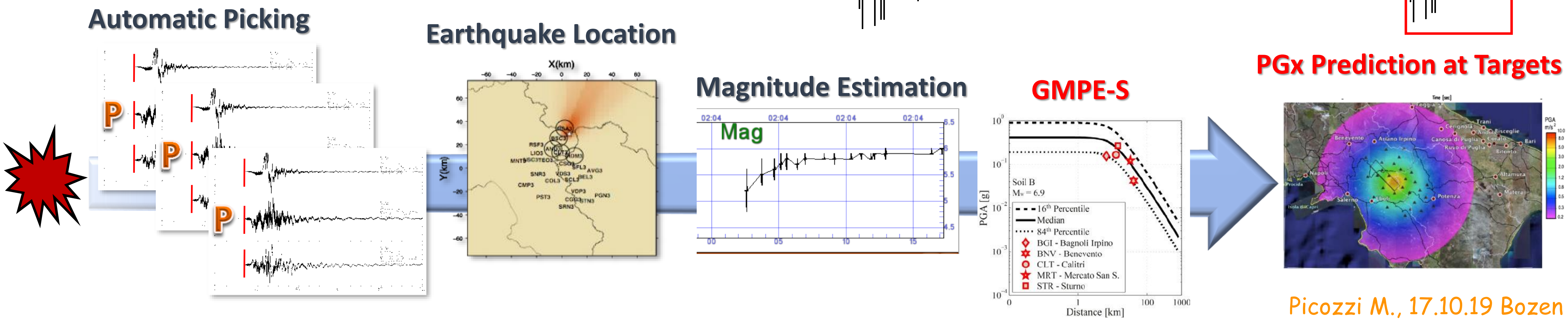


Lead-time:

(S-arrival time @ target) - (first-P @ network)

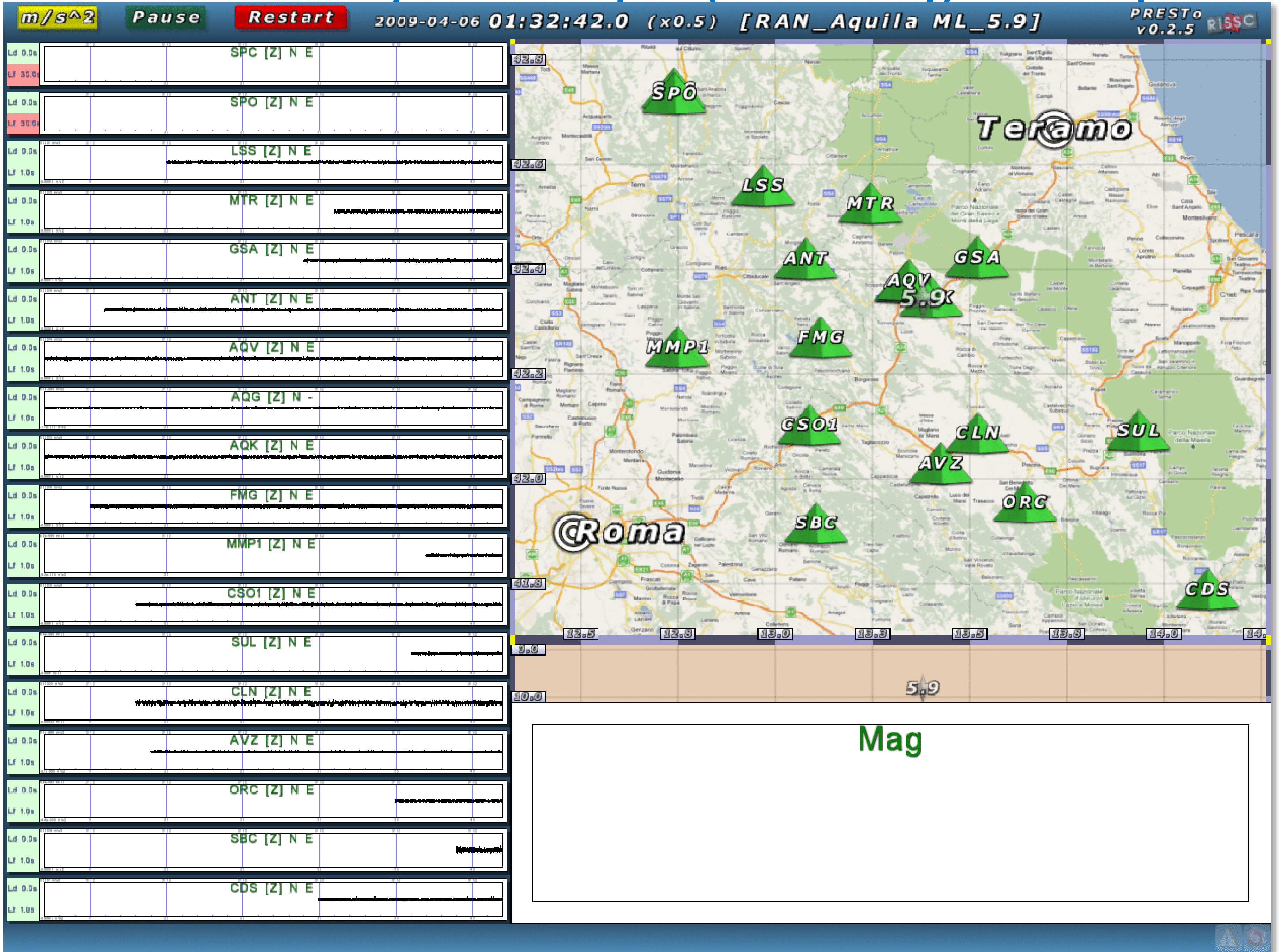




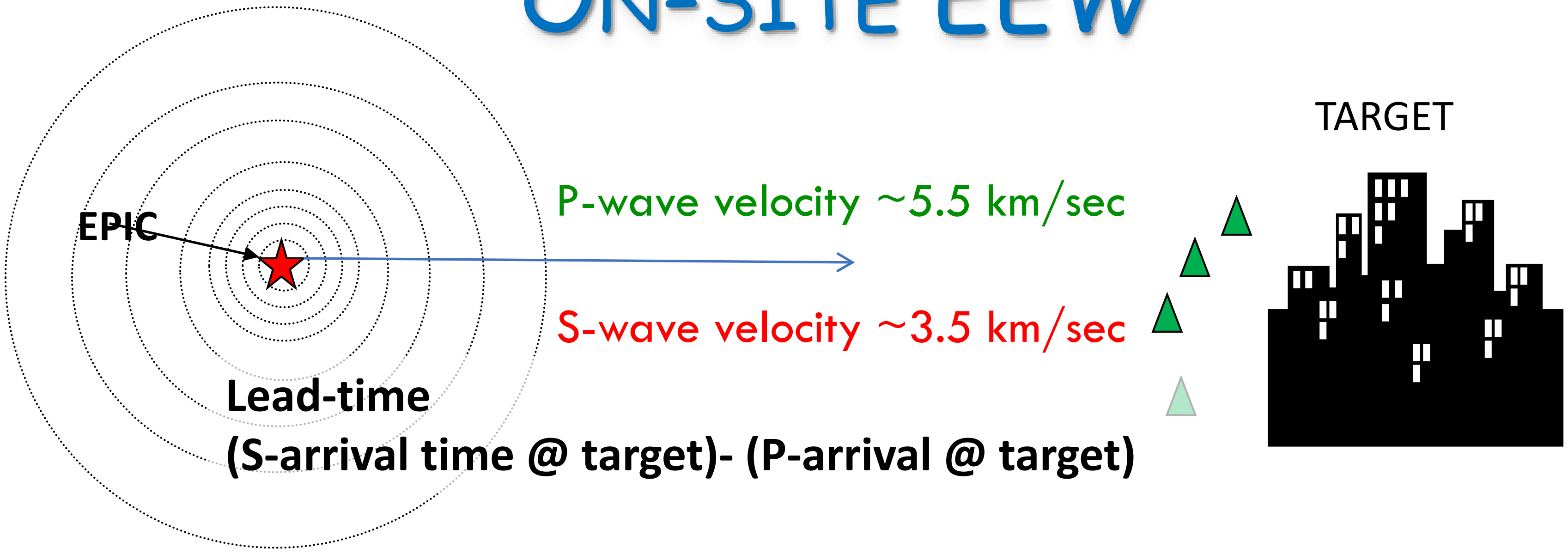


Picozzi M., 17.10.19 Bozen

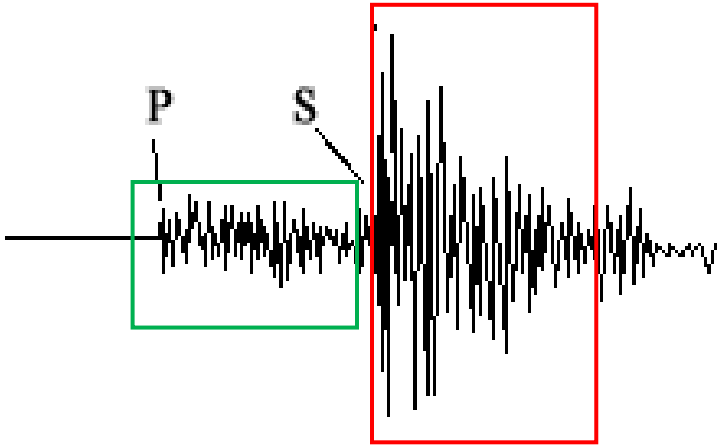
PRESTo PLUS Playback of L'Aquila (Central Italy) ML 5.9 Eqk



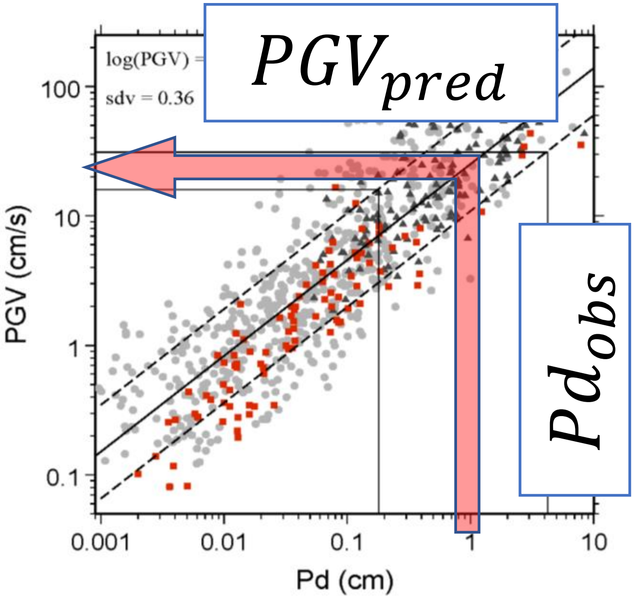
ON-SITE EEW



By-passing Location and Magnitude



S-wave ground motion



P-wave proxy

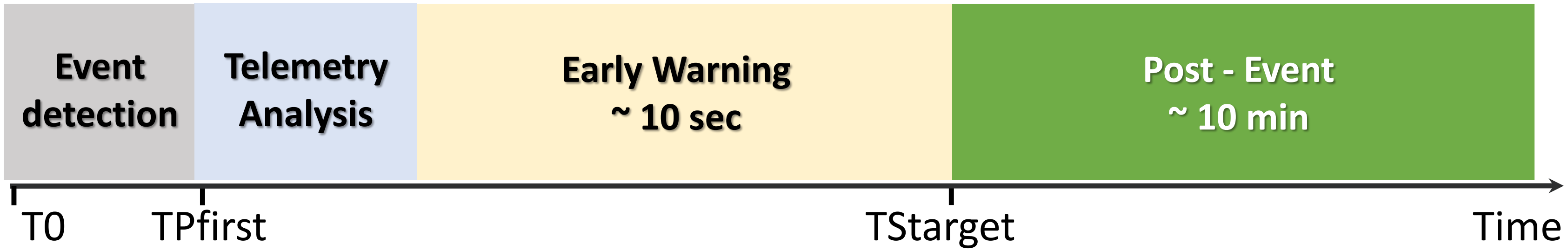
INTENSITY

Alert!!

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Stron	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Ligh	Moderate	oderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-1	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-1	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Modified Mercalli Intensity scale based upon Wald et al., 1999.

CRITICAL ISSUE → TIMING



Time efficiency of a system:

Off-Line: *no constrain* is set on the response time of the system.

Near Real-Time: the system is *fast*, but *no deadline* is set (the system can accumulate delays in special or critical conditions);

Real-Time: the system has to be *fast* and to react to an event (earthquake) within a given *deadline*;→nowadays: data packet < 1 sec

A real-time system for EW is a device (hardware or software) which reacts to an event within a <u>well defined deadline</u>

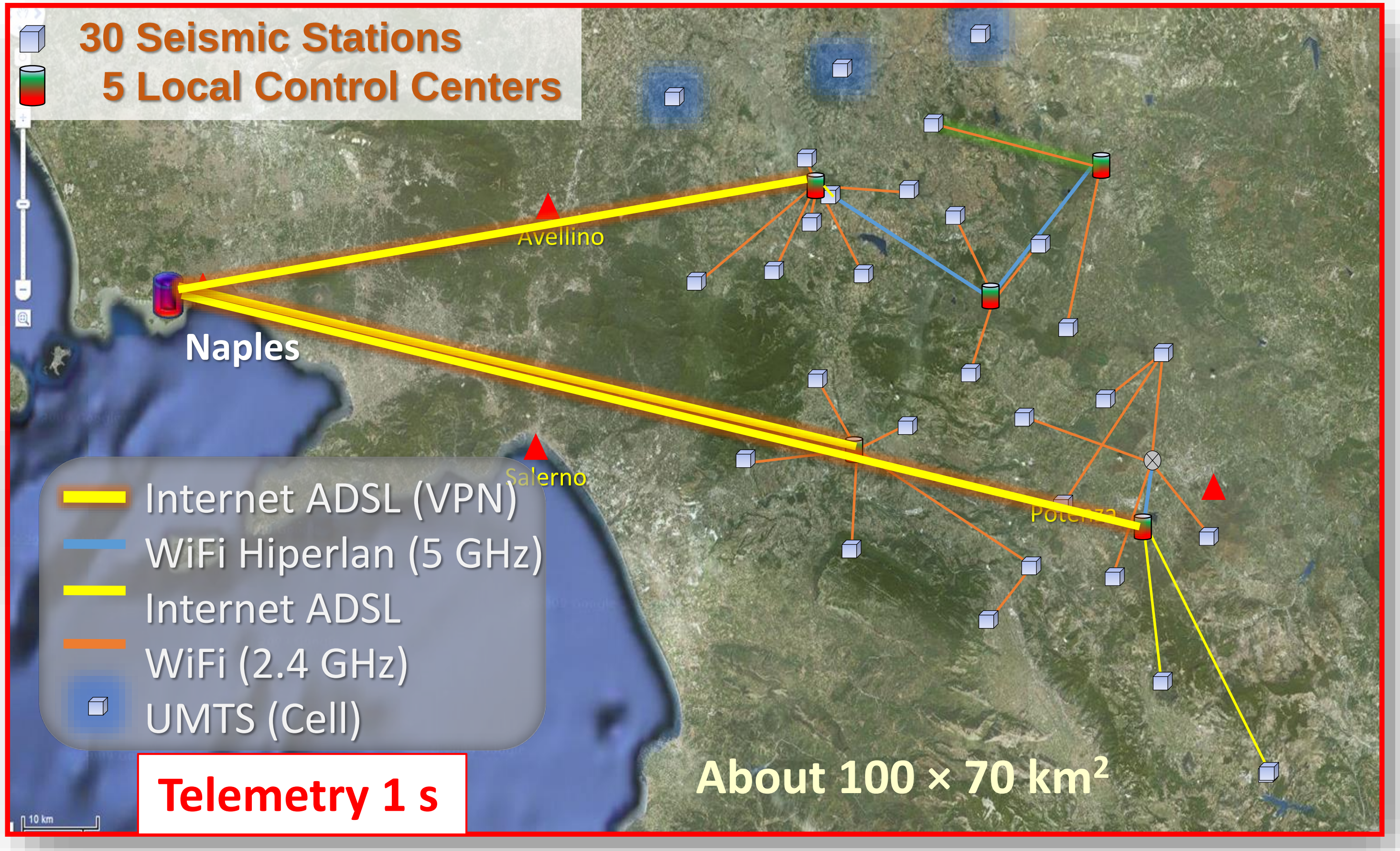
ISNet – Irpinia Seismic Network

since 2009

Southern Italy

Digitizers

Sensors

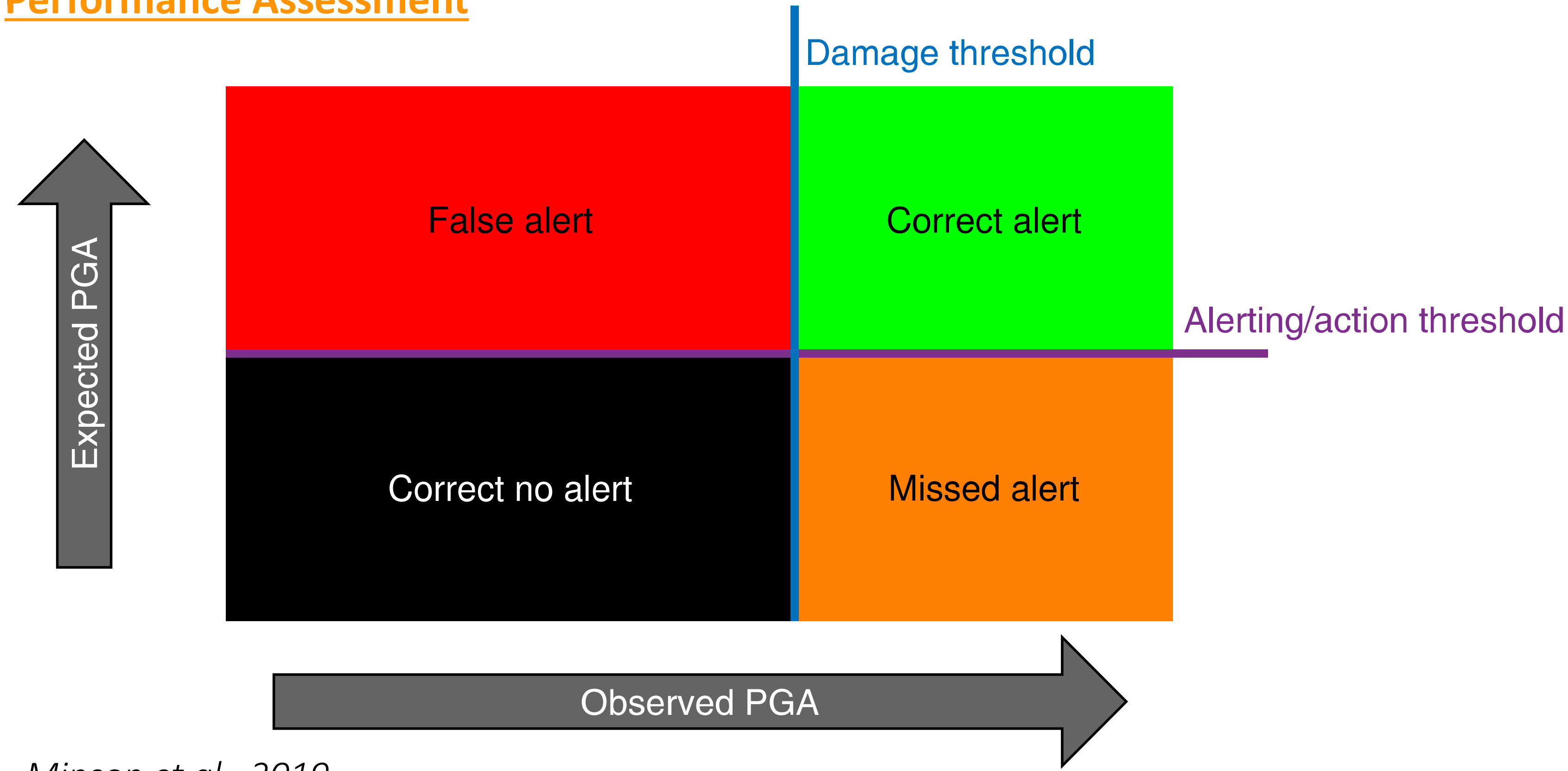


Digitizers – only those implementing the data transmission designed for EEW applications (latency < 1 second)

Once a threshold level for transmitting alerts is defined, considering the real data (e.g., PGAo) the alert follows a binary condition:

- necessary alert if observed PGA >= threshold
- not necessary alert if observed PGA < threshold

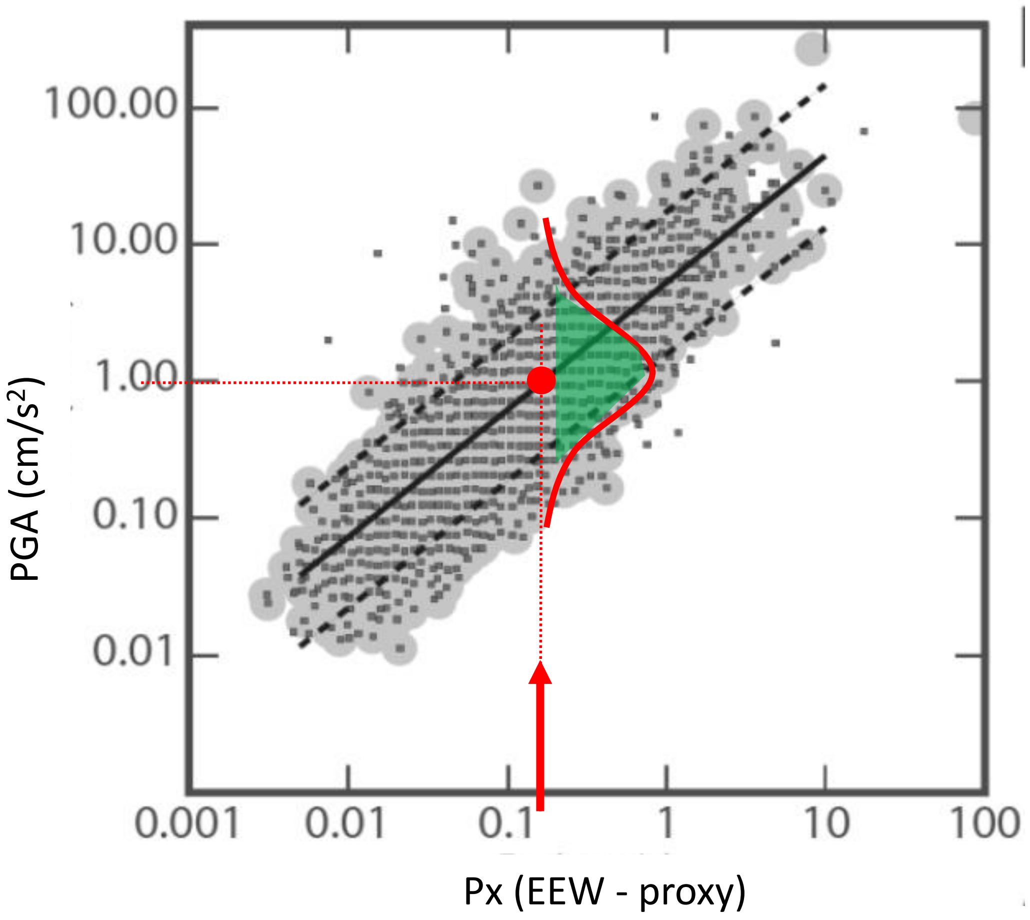
Performance Assessment



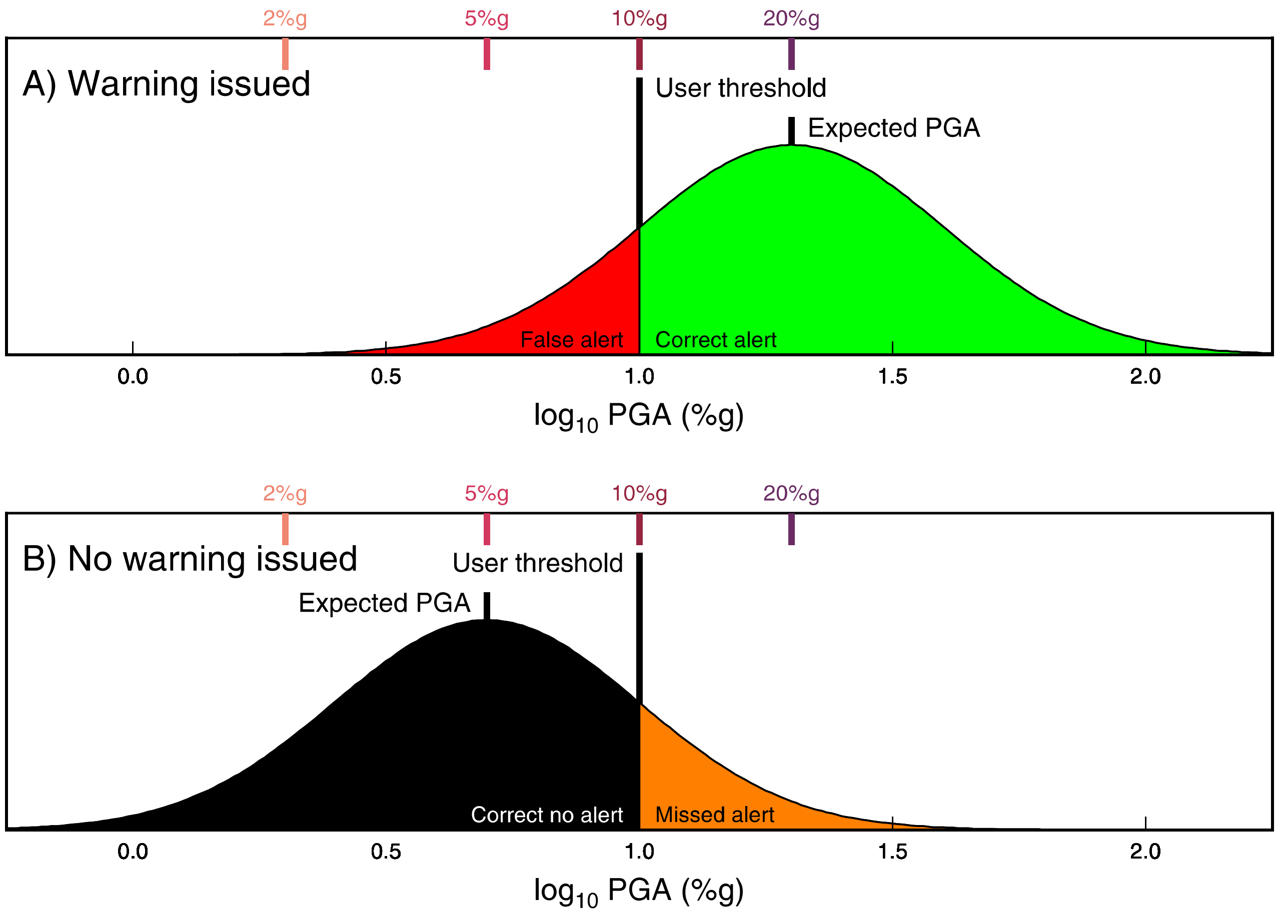
Minson et al., 2019

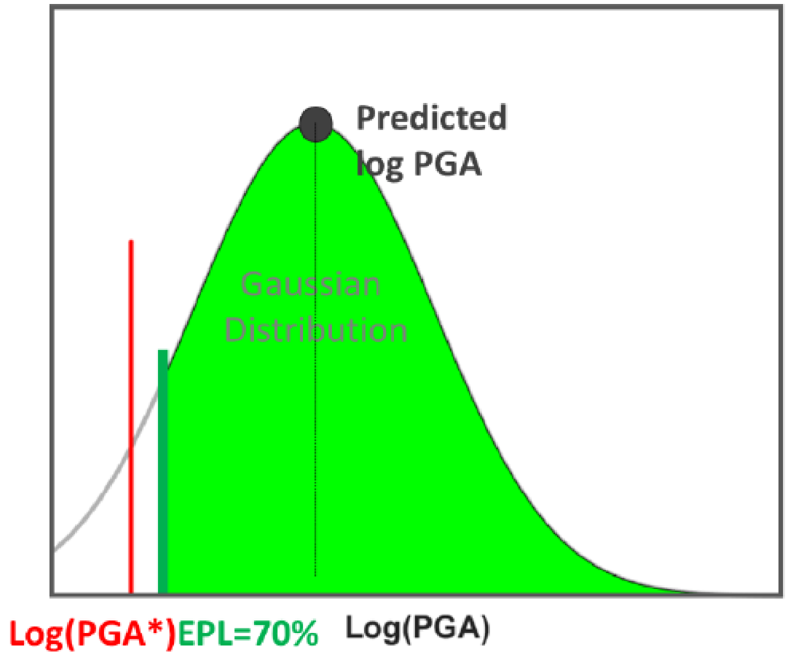
Critical issues

Data Uncertainty



Follow probabilistic approaches



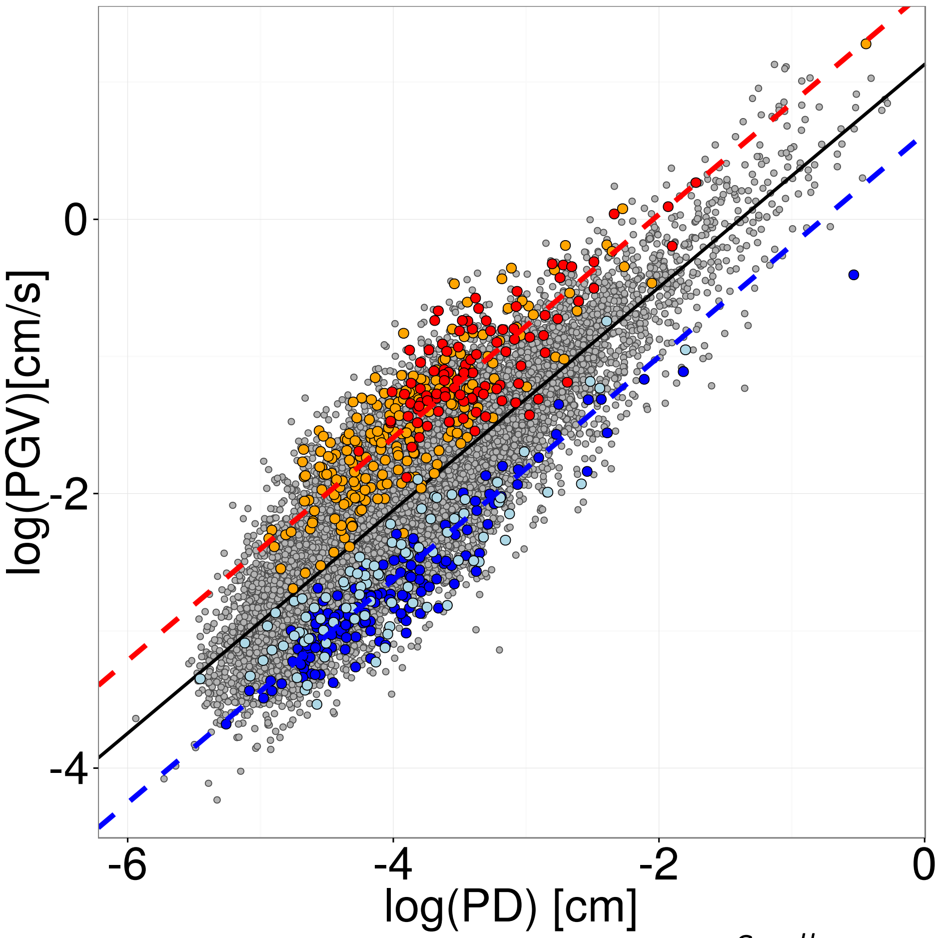


Action	example
Set the PGA threshold	$PGA = 2\,\%g, 5\%g, 10\%g, 15\%g$
Define the ***EXCEEDING PROBABILITY LEVEL (EPL)***, starting from the Gaussian distribution associated to any predicted log PGA value.	$LPGA^* \rightarrow Prob(LPGA \geq LPGA^*) = \mathrm{EPL}$
Declare an alert when the LogPGA predicted by P-wave peak amplitudes exceeds the threshold value	ALERT$\rightarrow$ Predicted $LPGA \geq LPGA^*$

Critical issues

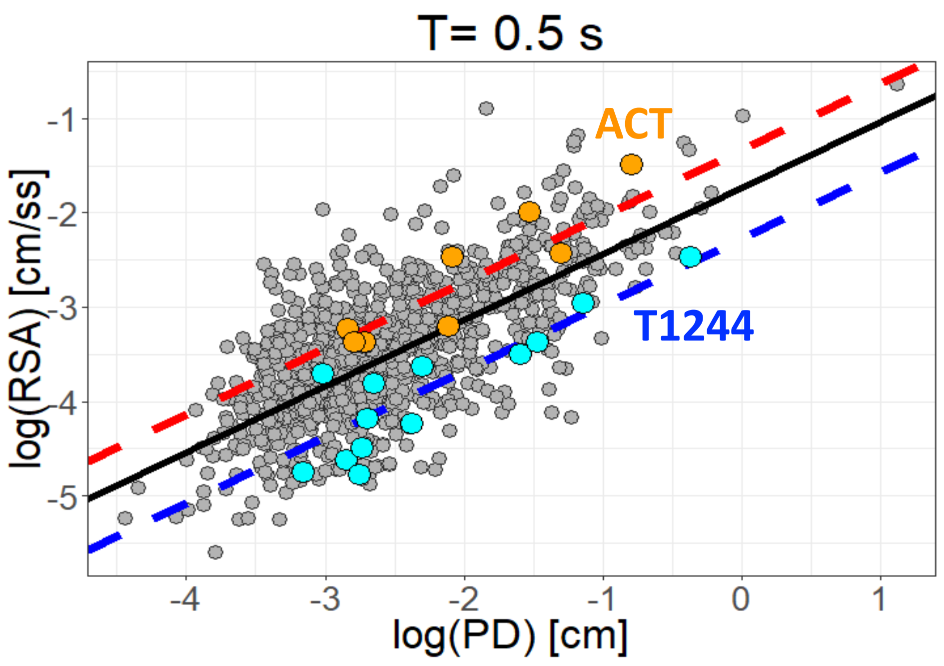
Model Uncertainty

$$Log\,PGV_{es} = a_1 + a_2 \log PD_{es}$$



Spallarossa et al., 2019

Model Uncertainty → EEW performance



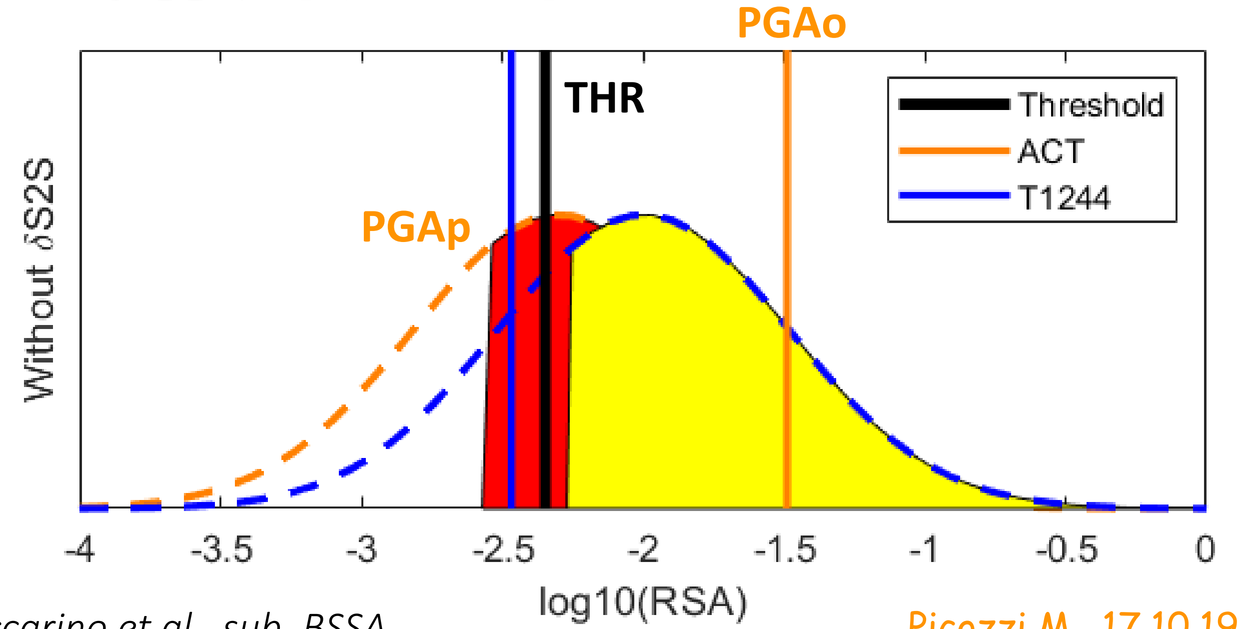
Model parameterization using ergodic assumption

$$log_{10}RSA(T) = a^{Pd\text{-}C} + b^{Pd\text{-}C}log_{10}(Pd)$$

Ergodic assumption says that the local variability in ground motion is the same as the global variability

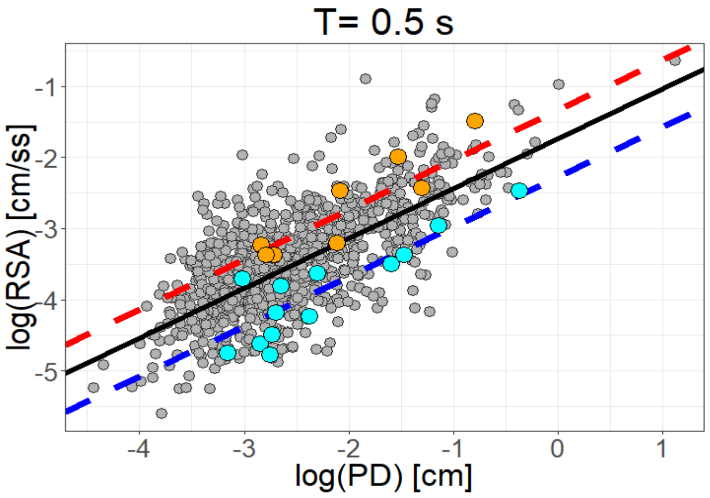
Ground motion residuals depend from several factors such as event, path and site

BAD EEW performance



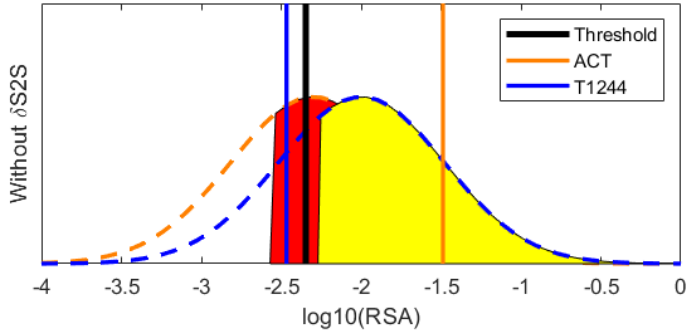
Iaccarino et al., sub. BSSA

EEW PERFORMANCE AFTER THE MIXED-EFFECT REGRESSION

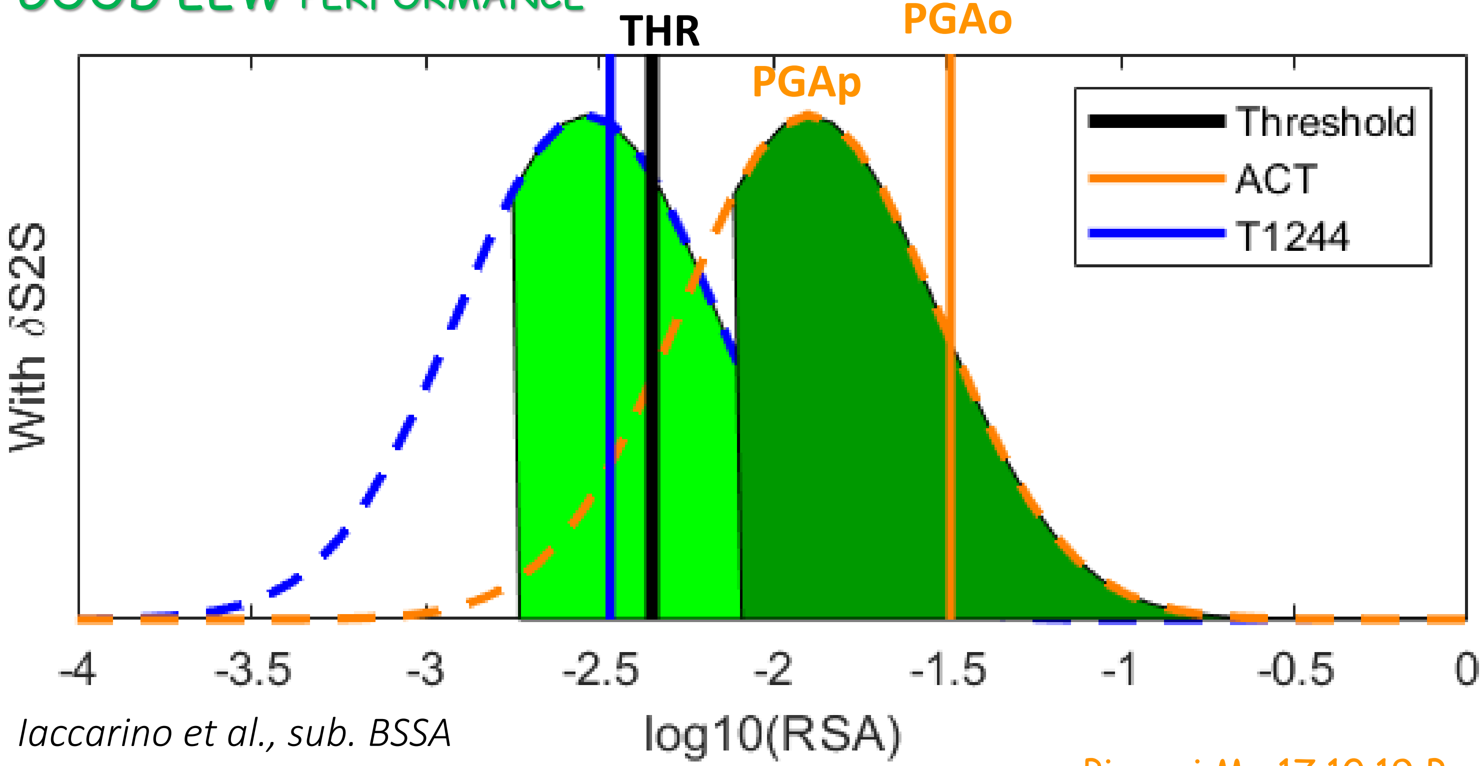


Model parameterization considering random effects

$$log_{10}RSA(T) = a^{Pd\text{-}C} + b^{Pd\text{-}C}log_{10}(Pd) + \underline{\underline{\delta S2S^{Pd\text{-}C}}} + \epsilon^{Pd\text{-}C}$$



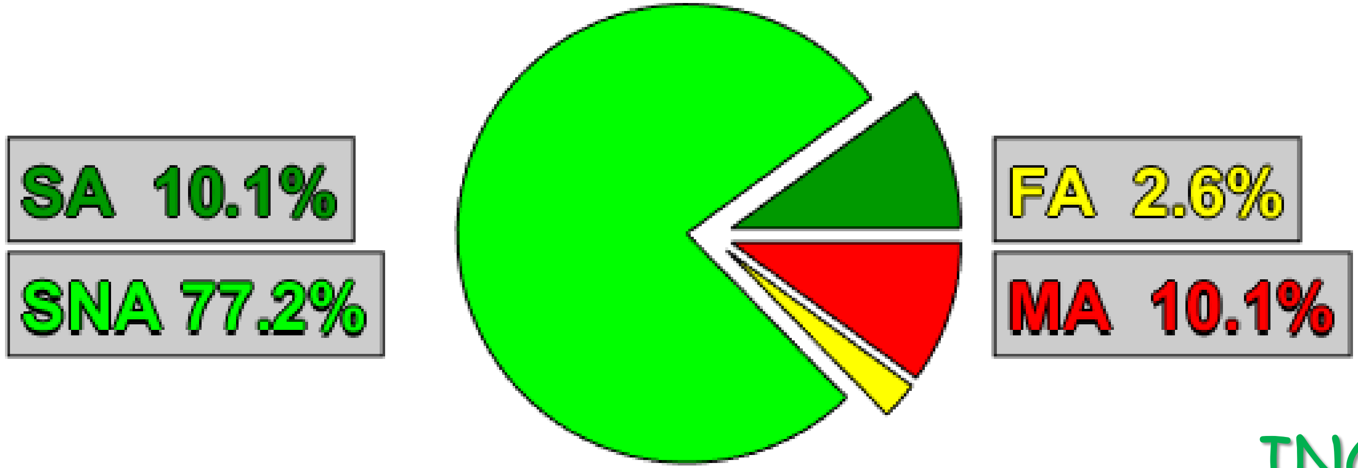
GOOD EEW PERFORMANCE



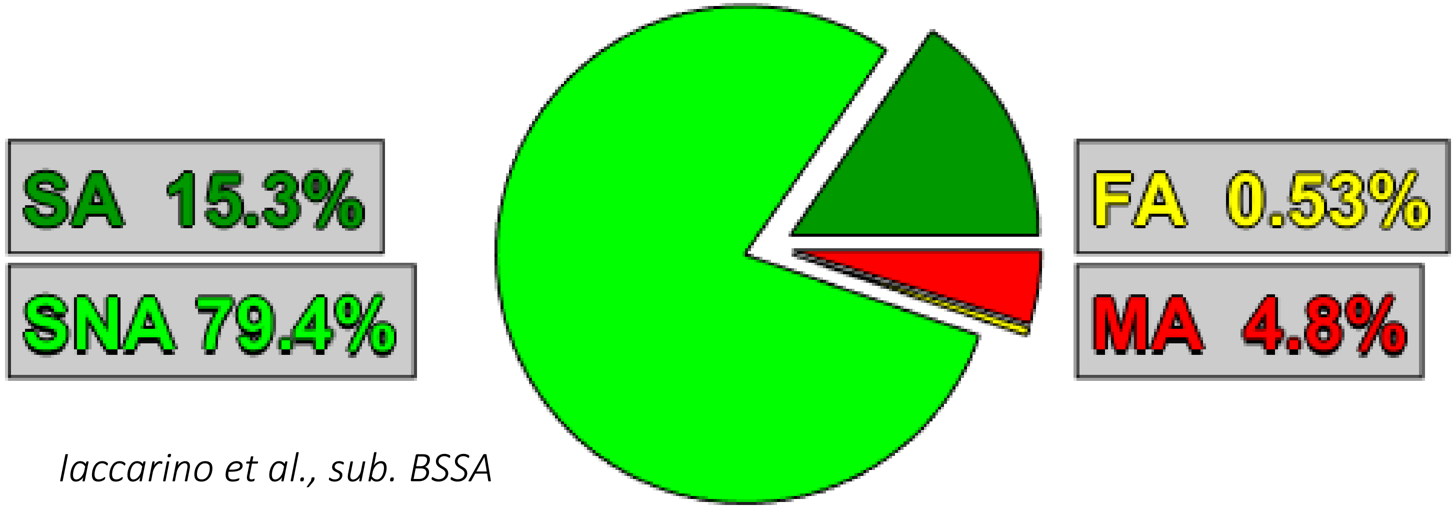
Iaccarino et al., sub. BSSA

EEW performance (~200 records @ ATM & T1244)

without random effects (ERGODIC)



INCLUDING RANDOM EFFECTS



Iaccarino et al., sub. BSSA

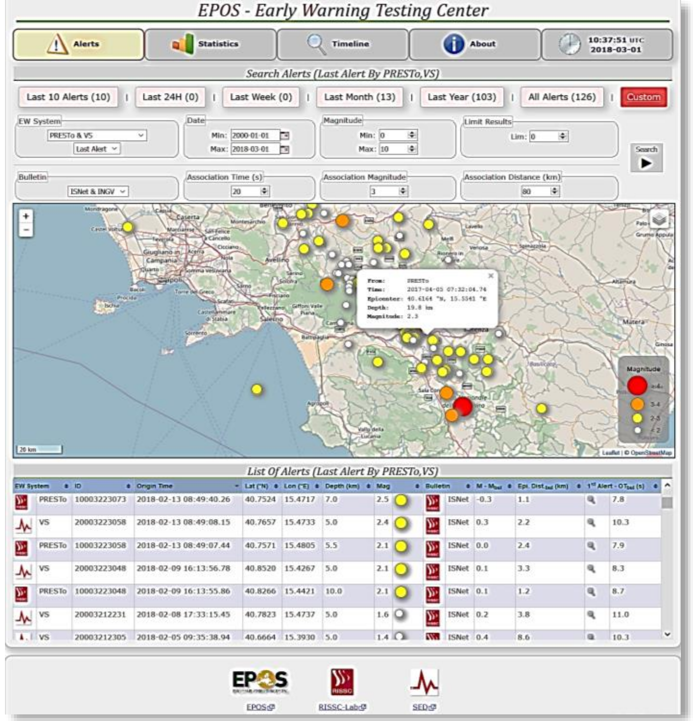
A COMMON FRAMEWORK FOR TESTING AND VALIDATING EEW SOFTWARE

EPOS NEAR-FAULT OBSERVATORIES

Testing Center for EEW in which different algorithms and procedures for EEW are running in parallel and compared.

CREW: Testing CenteR for Early Warning @UniNa

- Several EW software can run in parallel as Virtual Machines.
- **PRESTo** (UniNa) and **Virtual Seismologist** (ETH) are under testing
- **Standardized** inputs and outputs
- Database of all realtime alerts and of bulletins (ISNet, INGV)
- **Performance comparison**:
  Correctness of location and magnitude
  Promptness of the alert

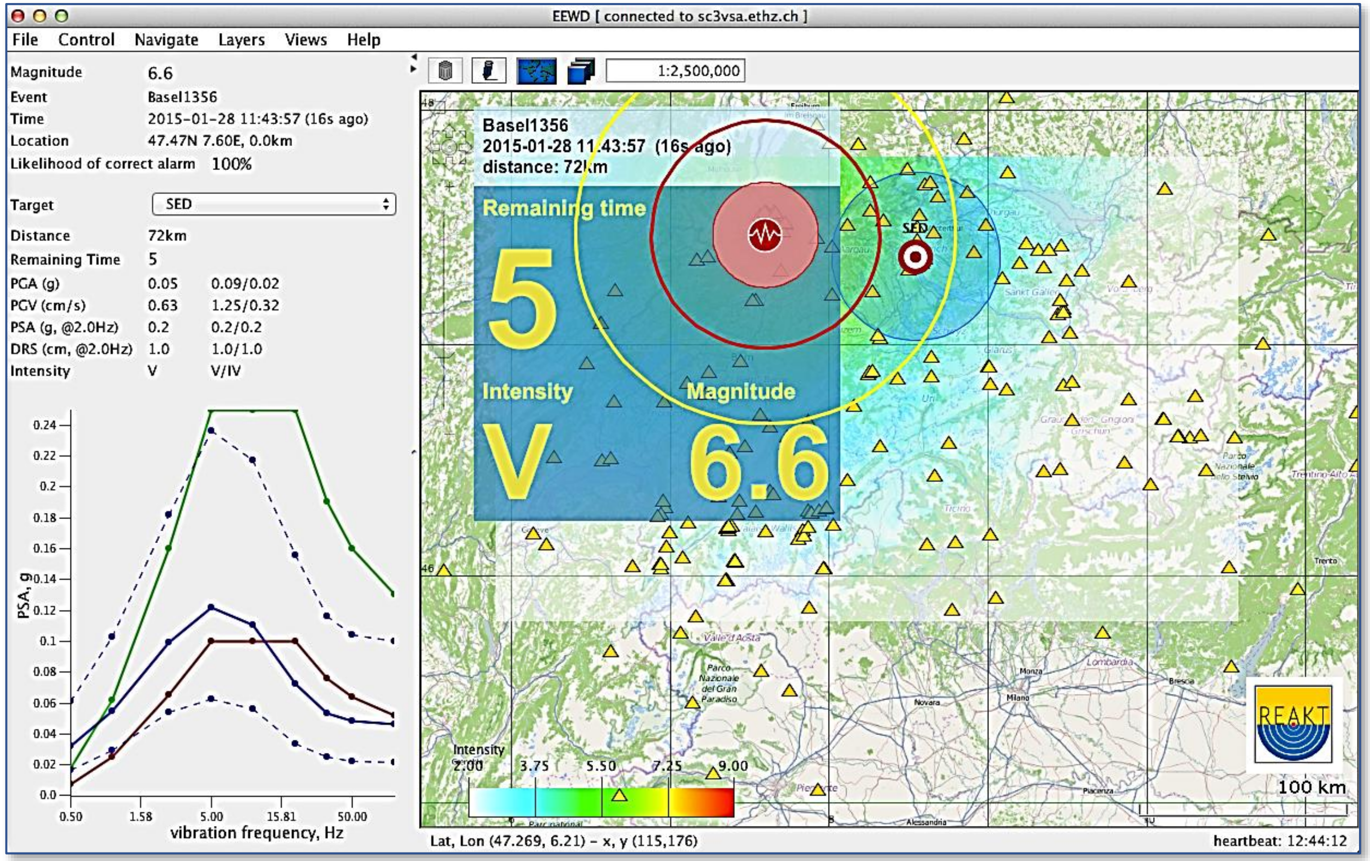


EEWD: Earthquake Early Warning Display

Application to quickly and easily understand the EW alert to the end user

Establishes a common format for the alert message

Configurable for the region (GMPE) and local effects of interest



How to reach the End-users

A Mobile App for PRESTo

Basic

- Geolocate the position of the smartphone
- Provide a warning in case of a potentially damaging seismic event
- Give instructions on how to behave
- Easily communicate the position & conditions through SMS and social networks

Expected Intensity

Expected Shaking

Available Lead Time

Instructions

How to reach the End-users

Bas

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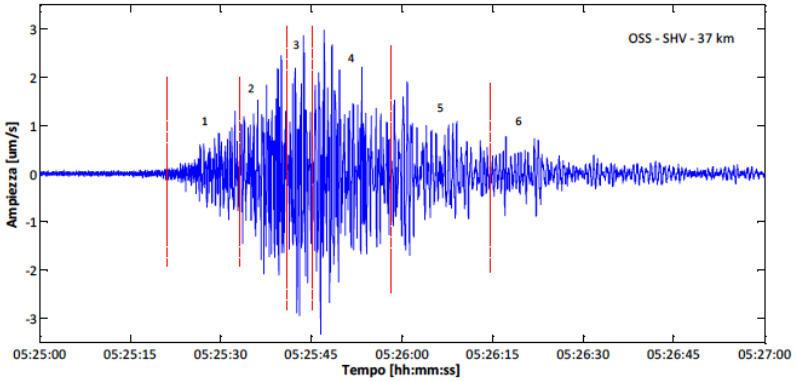
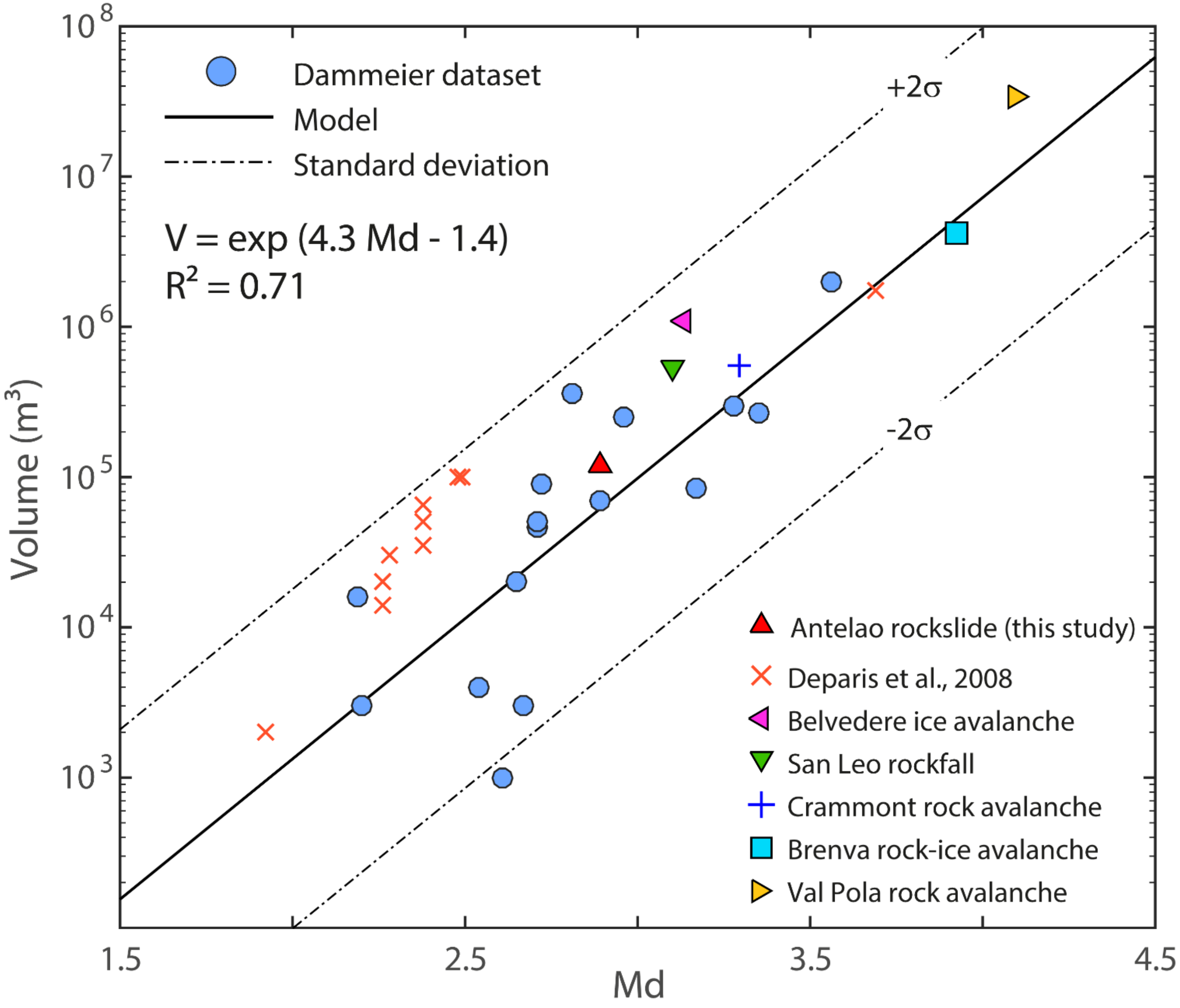
MASS WASTING EVENTS AND SEISMIC MONITORING

Val Pola landslide, 1987, Italy



Manconi et al., GRL, 2016



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Dipartimento di Fisica

riss
Realtime Innovative Solutions for Seismology
www.riss-srl.com

Pilot project: SlideQuake v0.1.0 (UniNA & CNR)

Antelao Rockslide

(2014, eastern Italian Alps)