ECGS & ESC/EAEE Joint Workshop 2015
EARTHQUAKE AND INDUCED MULTI-RISK EARLY WARNING AND RAPID RESPONSE
NOVEMBER 18-20, 2015

Worldwide Applications of PRESTo - Probabilistic And Evolutionary Early Warning System

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RISSC

http://www.rissclab.unina.it

Outline

- ✓ **PRESTo & PRESTo*PLUS***

- ✓ **Examples of worldwide applications**

- South Italy (Univ.Naples Fed II / AMRA)

- Romania (INFP/NIEP)

- South Korea (KIGAM)

- The Trans-National Seismological Network in the South-Eastern Alps (OGS, UniTS, ARSO, ZAMG)

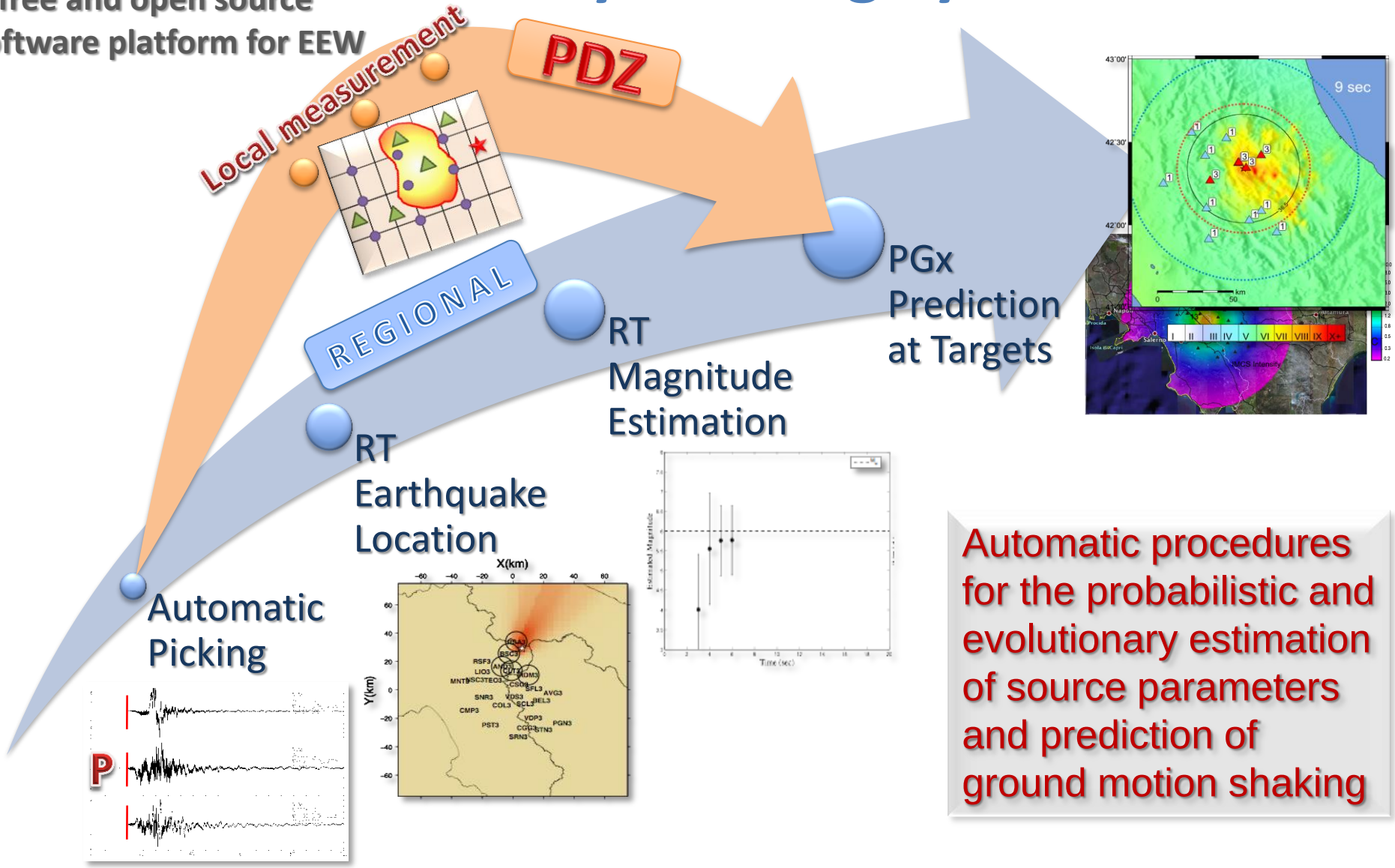
- PRESTO*PLUS* @ School – Southern Italy

PRESTo PLUS

Probabilistic and evolutionaRy Early warning SysTem

http://www.prestoews.org/

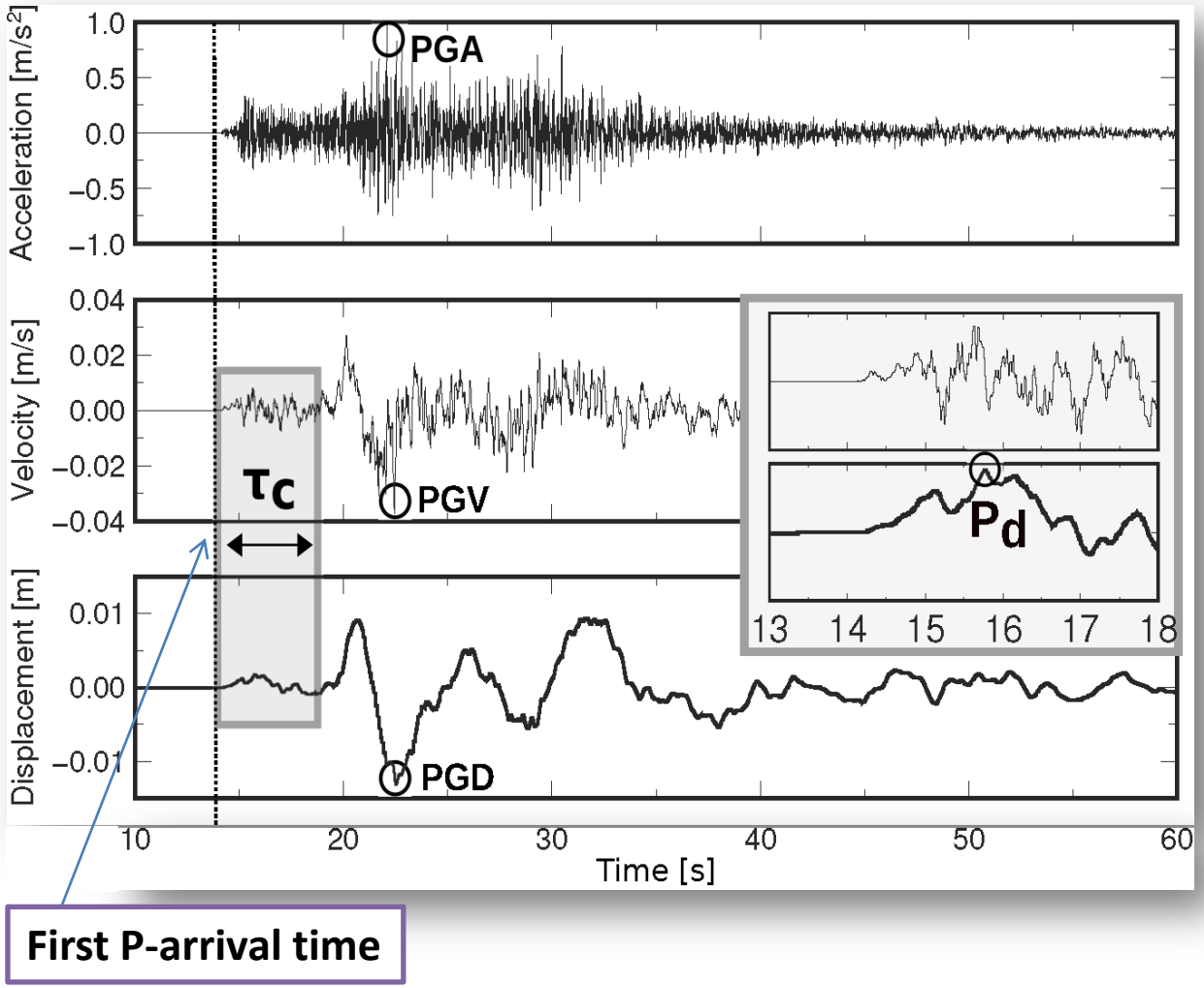
A free and open source software platform for EEW



Automatic procedures for the probabilistic and evolutionary estimation of source parameters and prediction of ground motion shaking

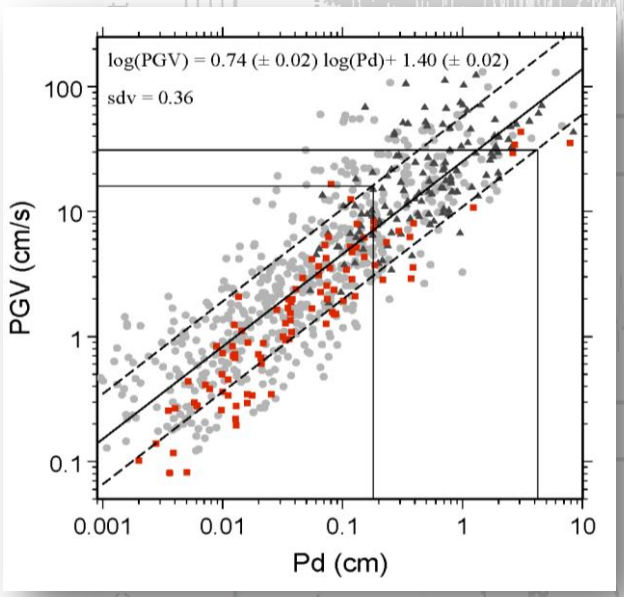
Satriano & al(2010). PRESTo, the earthquake early warning system for Southern Italy: Concepts, capabilities and future perspectives. Soil Dyn Earthquake Eng

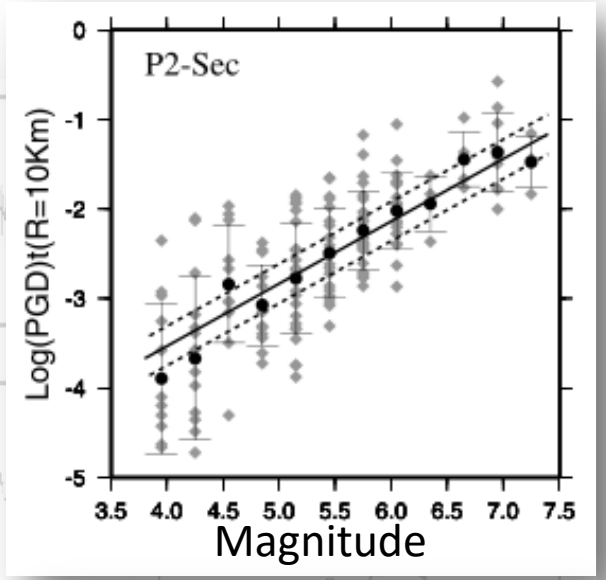
P-wave peak displacement & characteristic period



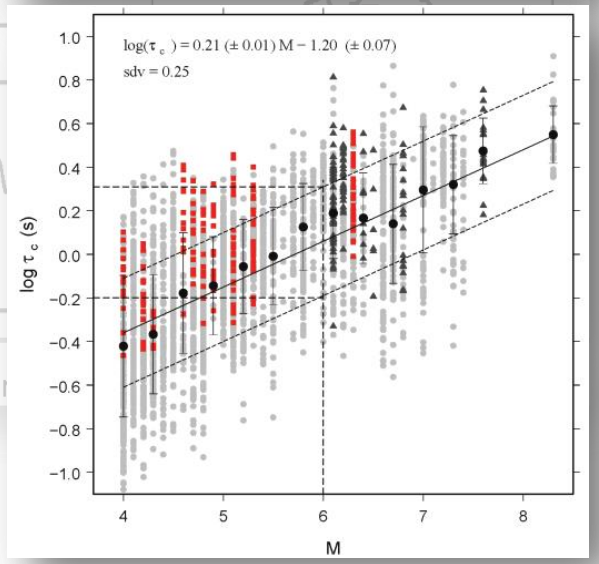
P-wave peak displacement & characteristic period

PGV vs Pd





Pd vs M



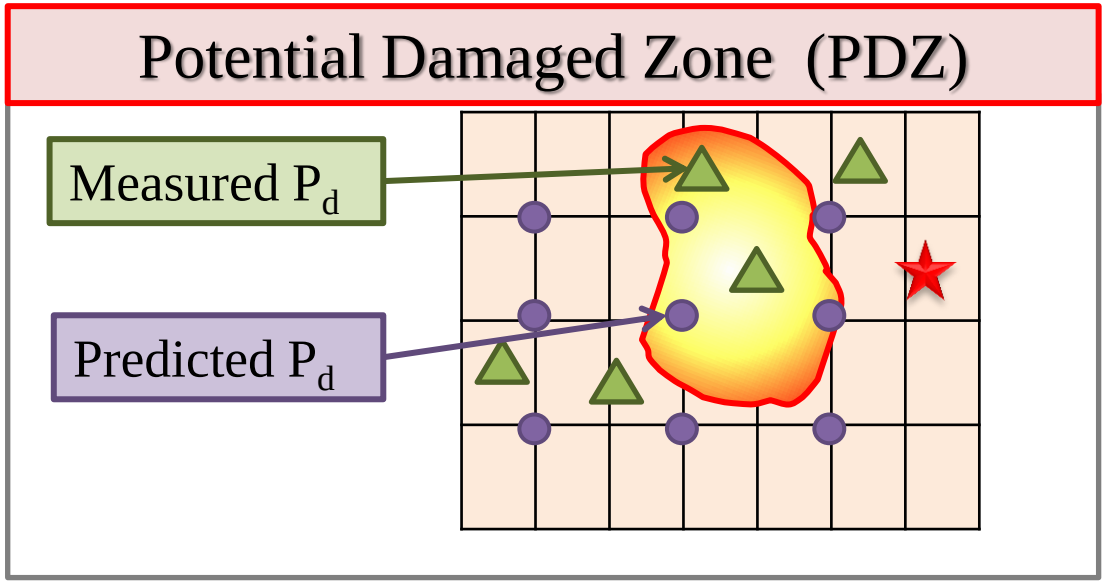
τ_c vs M

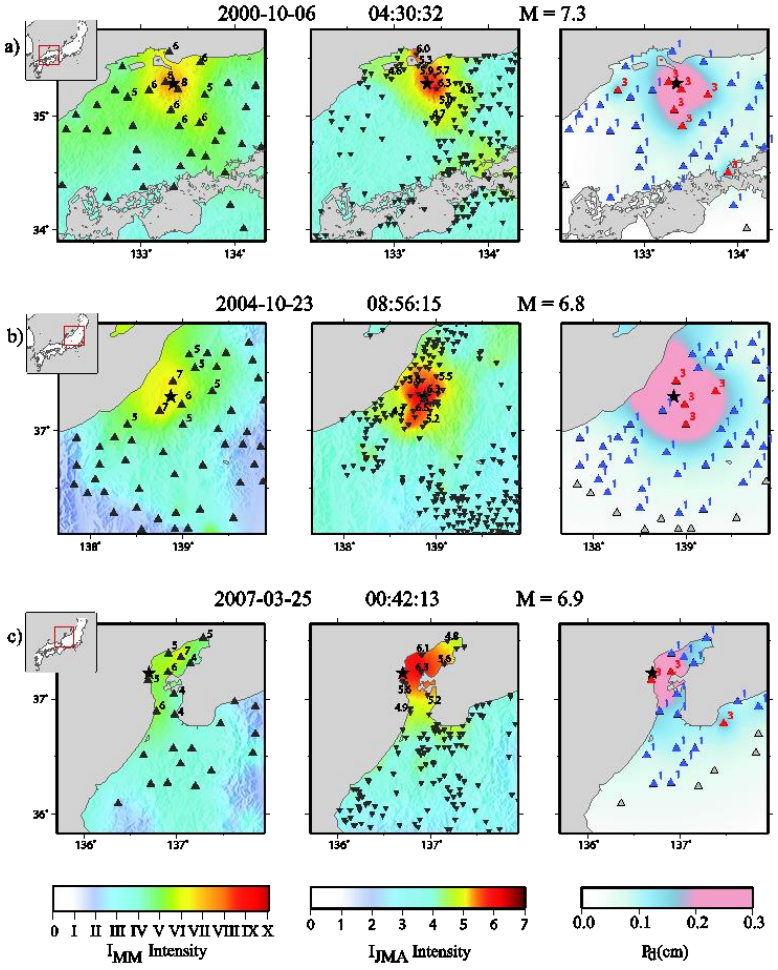
Empirical scaling relations of EW parameters

Rapid Damage Evaluation: the concept of Potential Damage Zone

Rapid estimate of the **Potential Damage Zone** by interpolating observed and predicted values of P_d

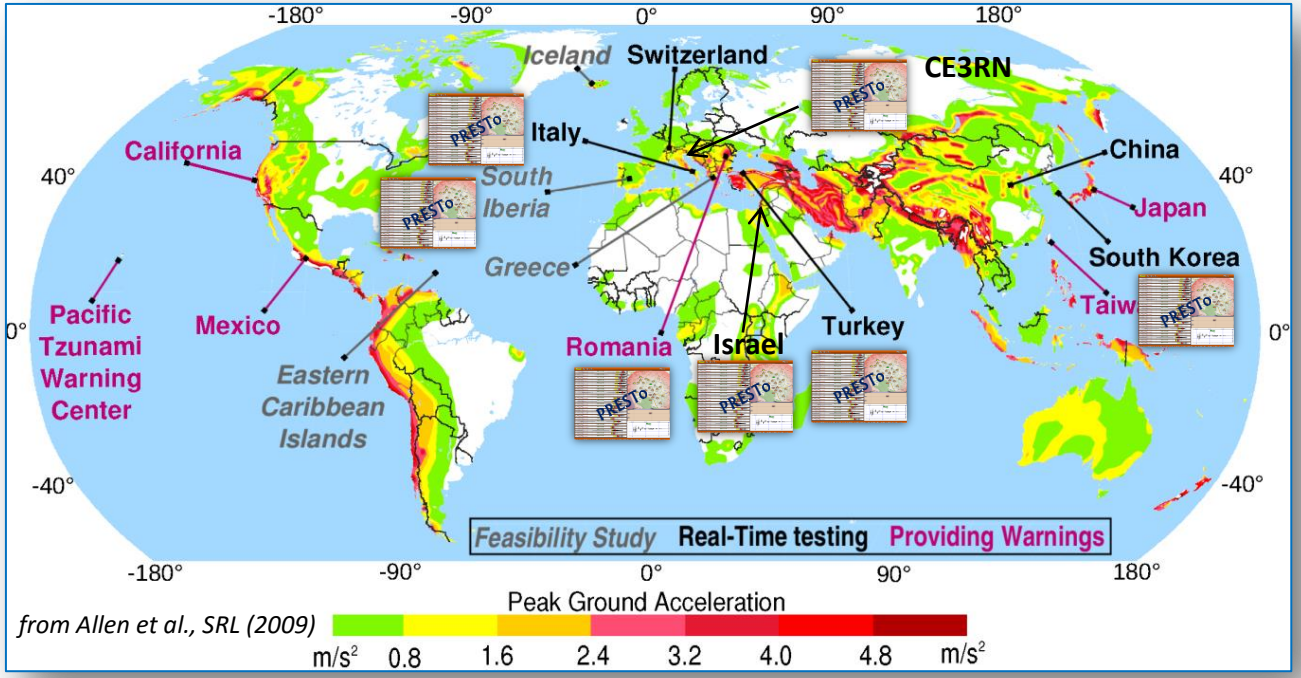
$$\log(P_d) = f(\log \tau_c, \log R)$$





Colombelli et al., 2012 BSSA

Worldwide Early Warning Systems & PRESTo



PRESTo is used/tested in:

- South Italy
- CE3RN (ITA-AUT-SLO)
- South Korea
- Turkey
- Romania
- Israel
- Spain

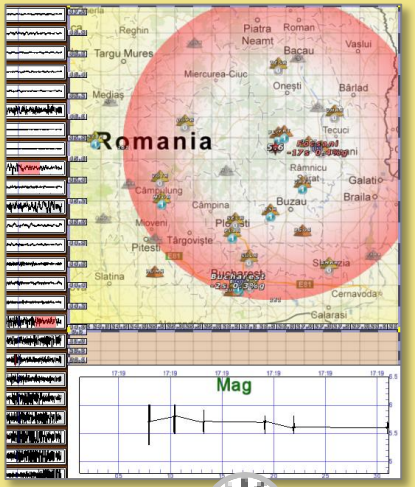
Download of PRESTo

Italy	30.74%
USA	9.59%
Brazil	6.28%
Korea	5.61%
India	5.01%
China	4.40%
Turkey	2.35%
Greece	2.26%
Ukraine	1.97%
Israel	1.95%
Taiwan	1.79%
Canada	1.59%
Iran	1.52%
Indonesia	1.43%
Romania	1.39%

PRESTo online

ROMANIA / RONET

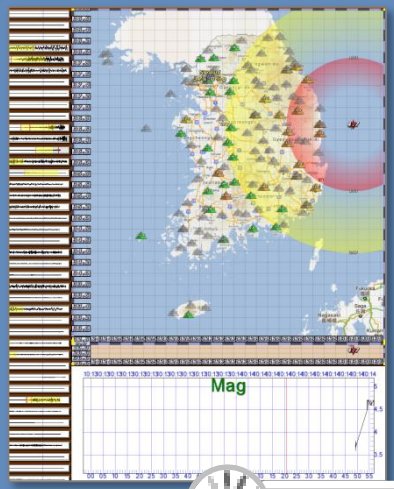
- RONET network
- **120 Stations** Real-Time
- **Tsunami EWS** (Romania & Bulgaria)
- High Seismicity (Vrancea Region)



REALTIME

KOREA / KIGAM

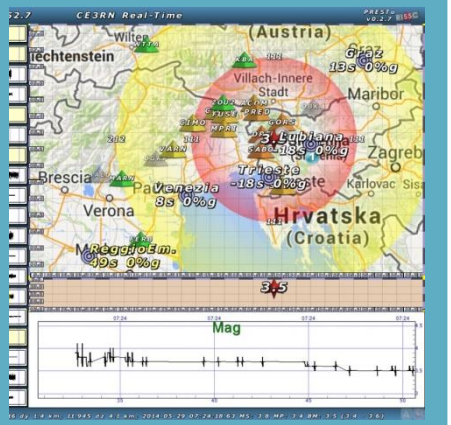
- KIGAM and KMA networks
- **200 Stations** Real-Time
- **Nuclear Monitoring** of North-Korea
- Low to Moderate Seismicity



REALTIME

ITALY/AUSTRIA/SLOVENIA

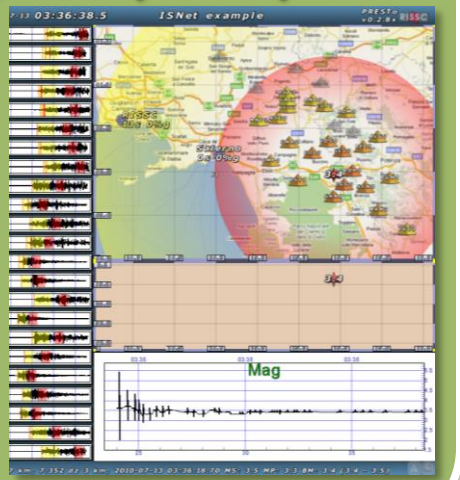
- CE3RN network: **Italy, Austria, Slovenia**
- **20 stations,** since begin 2014 in **real-time**
- **15 detection (1 False Alert)**



REALTIME

ITALY/ISNET/RAN

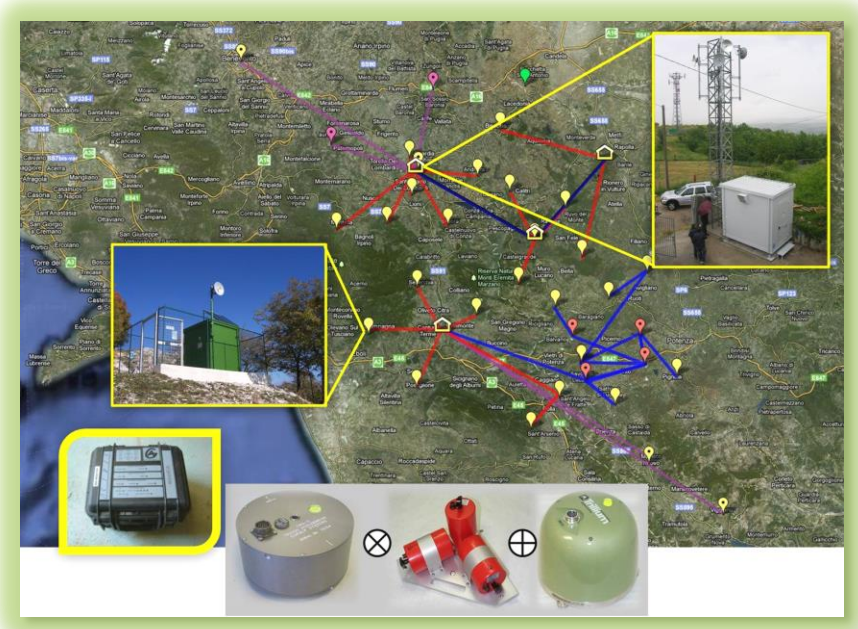
- ISNet network: **30 stations, 5 years real-time**
- Feasibility Study for **Nation Wide EWS (RAN 500 Stations)**
- Moderate Seismicity



REALTIME

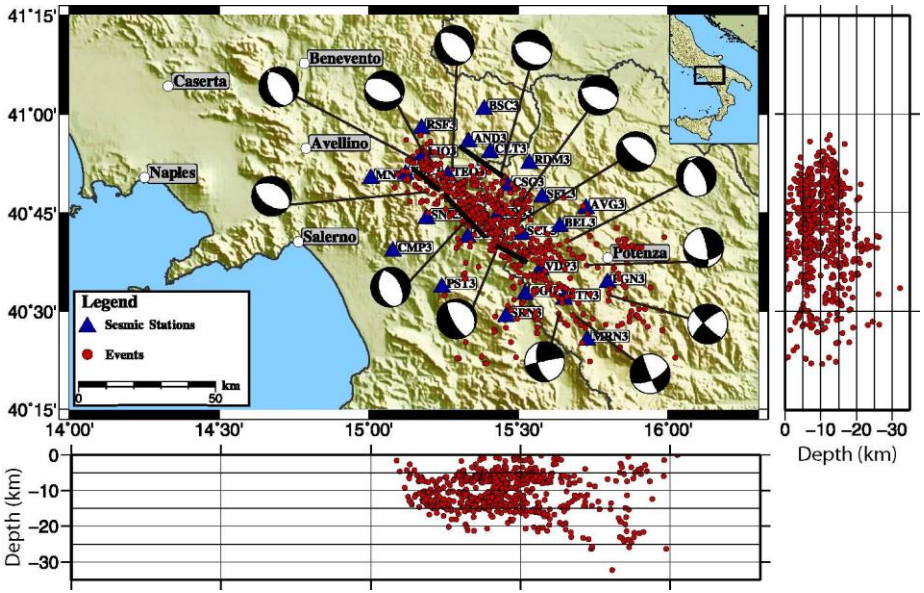
PRESTo@ISNET in South Italy

Network Configuration



30 6-C stations: accelerometers + velocimeters
5 local control centers, 1 Network Center
Mixed data transmission technology (ADLS, WIFI Hyperlan, UMTS)

Present-day seismicity

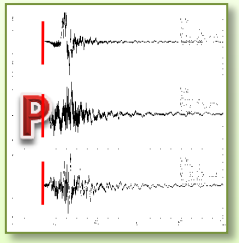


Microseismic activity (M<3.7) confined within the Ms 1980 Irpinia fault system (2007-2015)
Predominant Normal fault mechanisms
Shallow crustal depths (< 20 km)

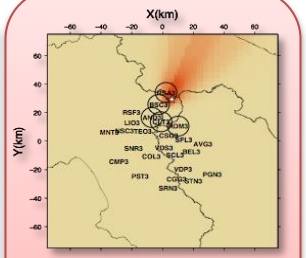
Early Warning Time-Line – PRESTo PLUS

SECS AVAILABLE TO TARGET

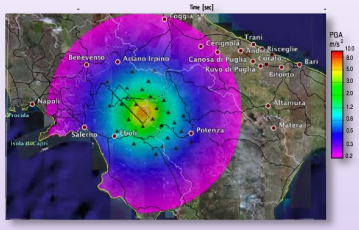
17 15 13 11 9 7 5 3 1



P-Waves at 1st Station



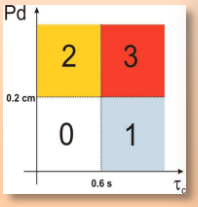
Probabilistic Location



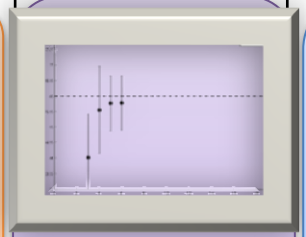
Regional Scale Peak Ground Motion

TARGET

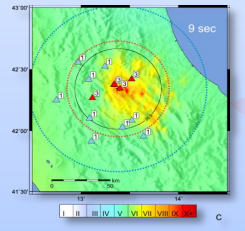
Origin Time



On-Site Alerts



Bayesian Magnitude



PDZ - Probable Damaged Zone

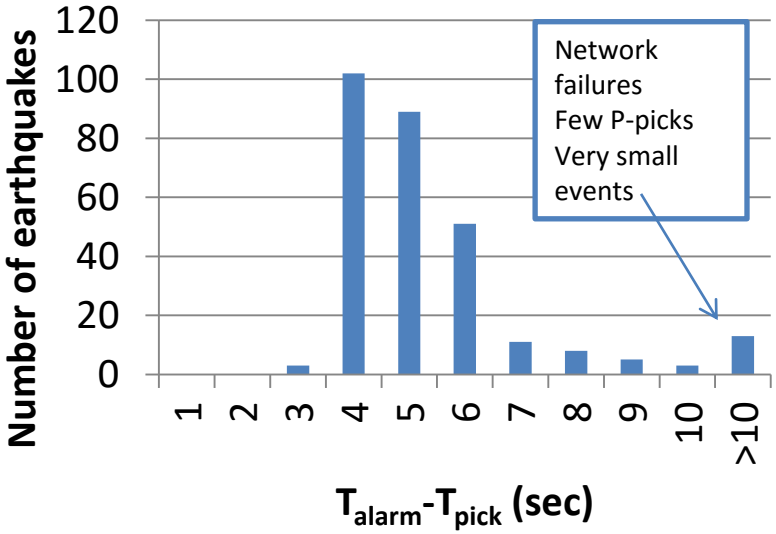
S-Waves At Target

0 2 4 6 8 10 12 14 16 18 20 22 24

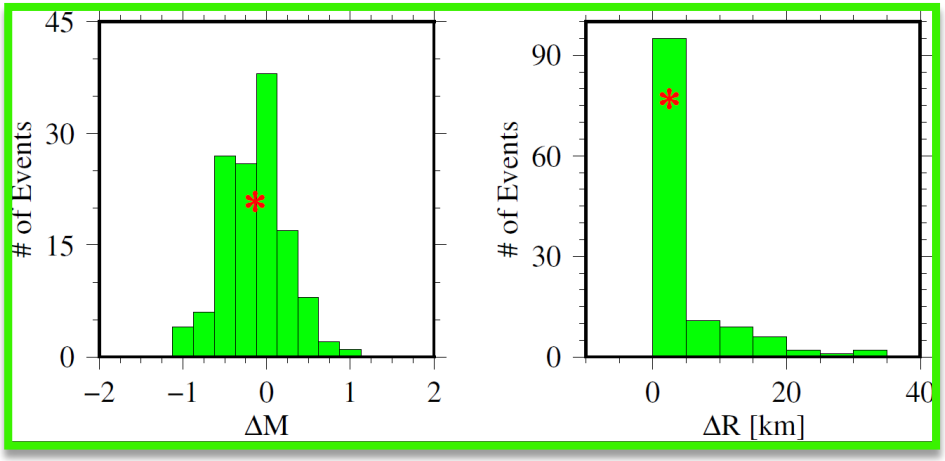
SECS FROM ORIGIN TIME

EW system performance (2010-2015)

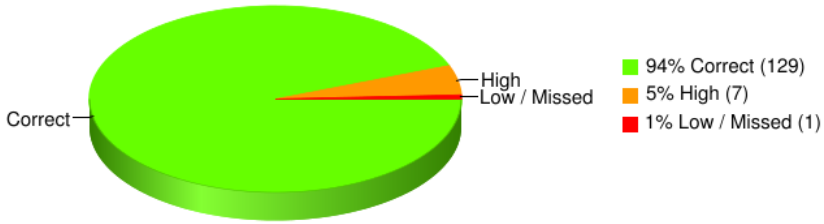
Time of first alert



Error on location and magnitude



Event detection performance



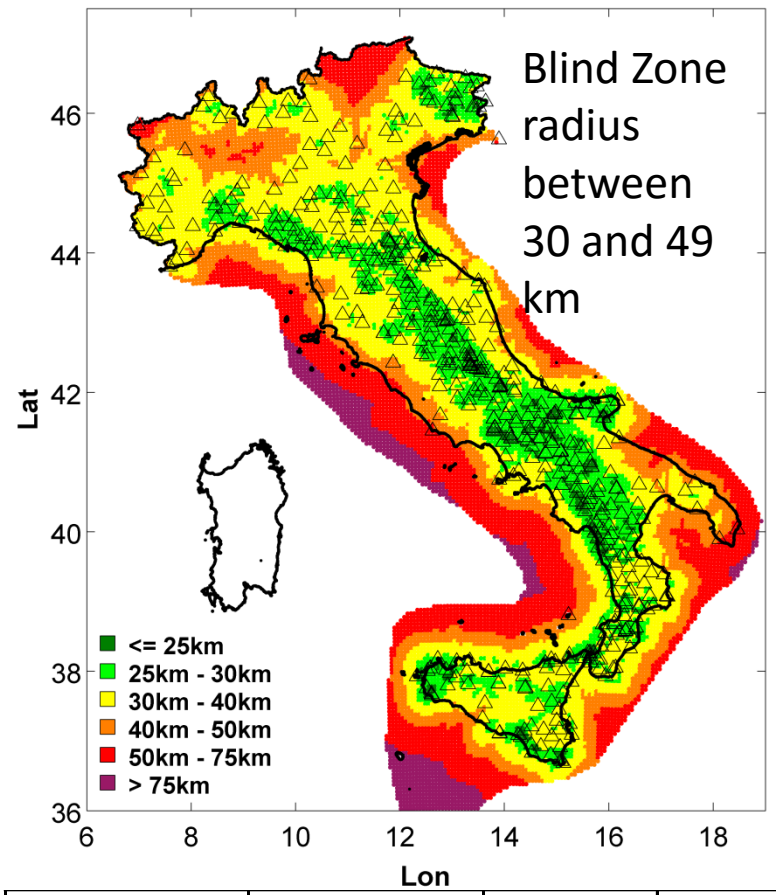
137 event with 2<M<3.7

Detection: Ok (94%), False (5%) Missed (1%)
First alert: 4-5 sec after first P-wave
Average error on magnitude : ~ 0.3
Average error on location : $\sim 5-7\ km$

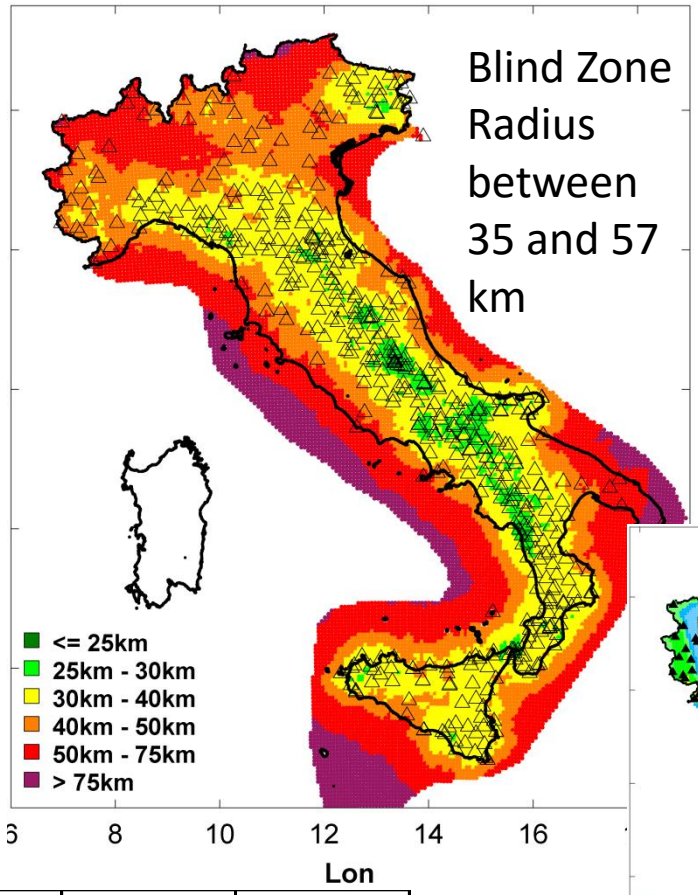
PRESTo Nation-Wide Performance Evaluation on RAN

Blind Zone

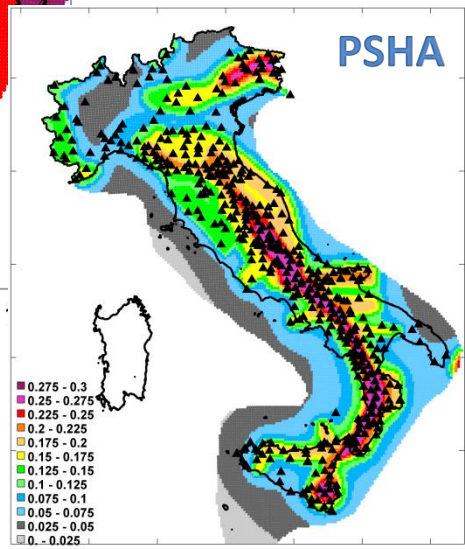
3 stations



6 stations



To compute the BZ radius: P-arrival time, P-wave time window, average telemetry and computation times at RAN.



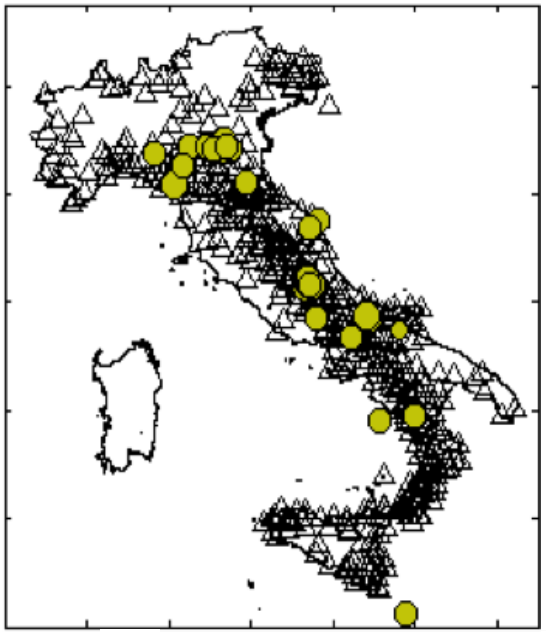
Parameter	*N. of stat.*	*I*	*II*	*III*	*IV*
BZ radius (km)	3	30.6	33.4	34.4	49.1
BZ radius (km)	6	35.5	39.4	41.0	57.4

Picozzi, M, et al (2015), Exploring the feasibility of a nationwide earthquake early warning system in Italy. J. Geophys. Res. Solid Earth

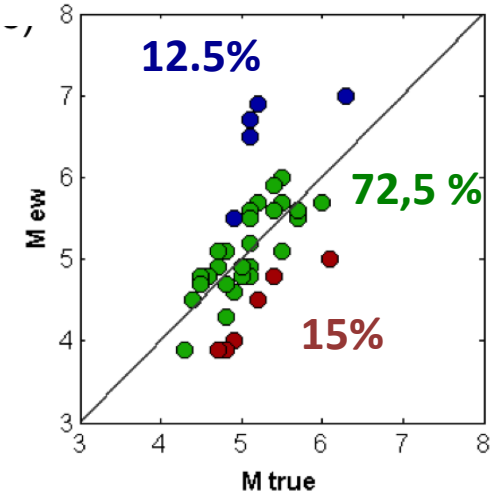
PRESTo Nation-Wide Performance Evaluation on RAN

Offline analysis of recent earthquakes

40 EQs, Mw>4.5, 2002-2013 from ITACA 2.0
(http://itaca.mi.ingv.it; Luzi et al., 2008; Pacor et al., 2011)



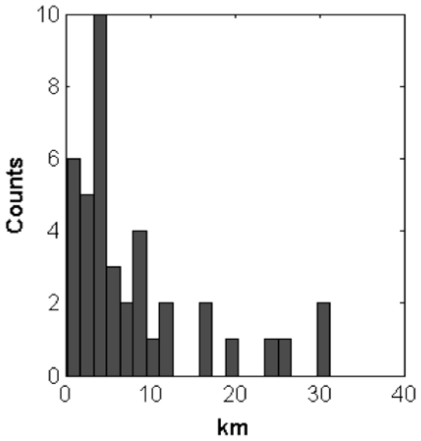
Magnitude (using 3 stations)

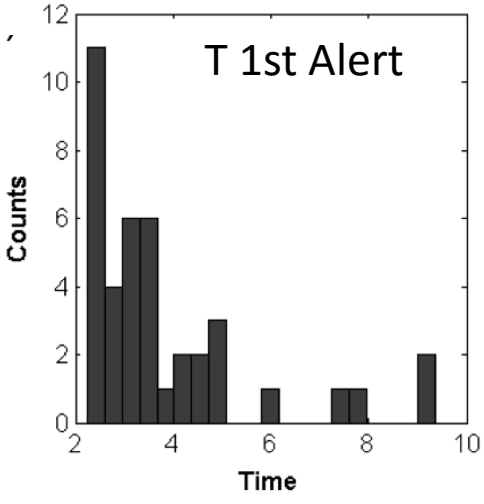


When a dense seismic network featuring real-time telecommunication is deployed in the fault area, PRESTo produces reliable estimates of the source parameters within 5-6 s from the first detected P-waves arrival

Location

Error on hypocenteral location





EEW in Romania

The tests of PRESTo^{Plus} at INFP/NIEP started in the 2012

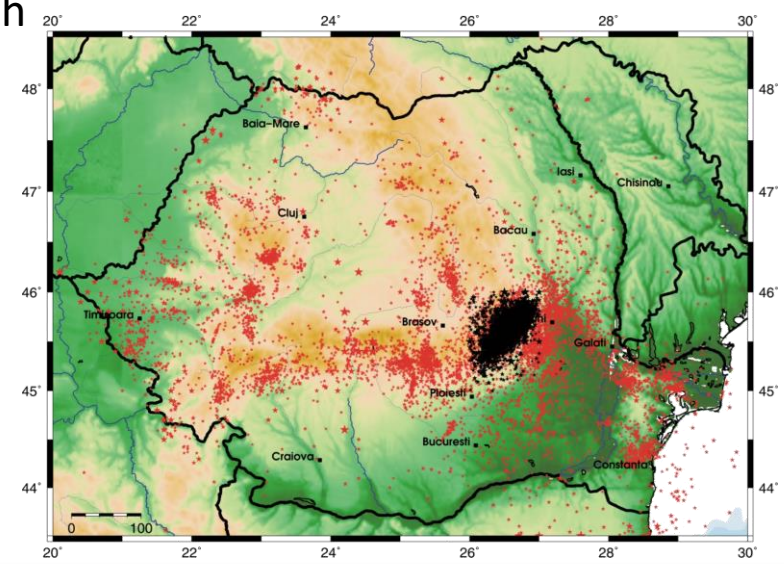
- Seismic risk in Romania dominated by deep Vrancea earthquakes
- 4 events M6.9 – M7.7 from 1940 – 1990. M7.2 1977 >1500 casualties, mainly in Bucharest.
- Operational EEW System (since 2013) used a network of 35 stations centered on Vrancea providing location and magnitude *focusing only on these deep events – now 120 stations*
- 25 – 35 s warning for Bucharest 130km to South

2 EEW algorithms in independent operation:

- **PRESTo** provides magnitude and location with modified magnitude relation for deep events
- Large threshold local algorithm to determine magnitude

EEW alert → ***if both algorithms trigger !***

In 2014 10 alerts sent (2 false alarms)



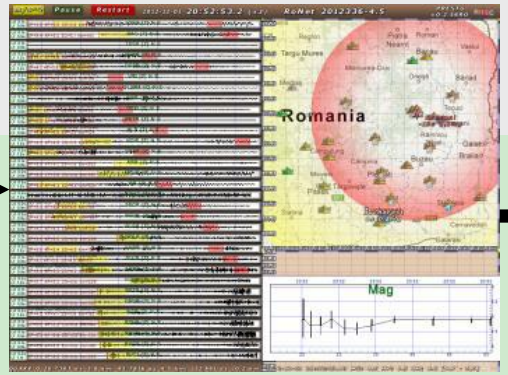
Earthquakes 984-2010 (ROMPLUS cat.)
Red=shallow, Black=intermediate depth
(from 70km to 180km)

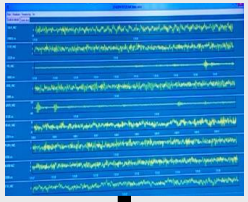
PRESTo in parallel with the existing NIEP's EEWS.
The integrated EEWS is in real time on RoNet since August 2013

ELEMENTS OF THE RAPID SEISMIC WARNING SYSTEM

Seismic stations

PRESTO
using strong motion network in Romania





NIEP
PLOR, VRI, MLR
strong motion station

+ 6 buffer stations

Validation system

25-40 sec. before the s wave

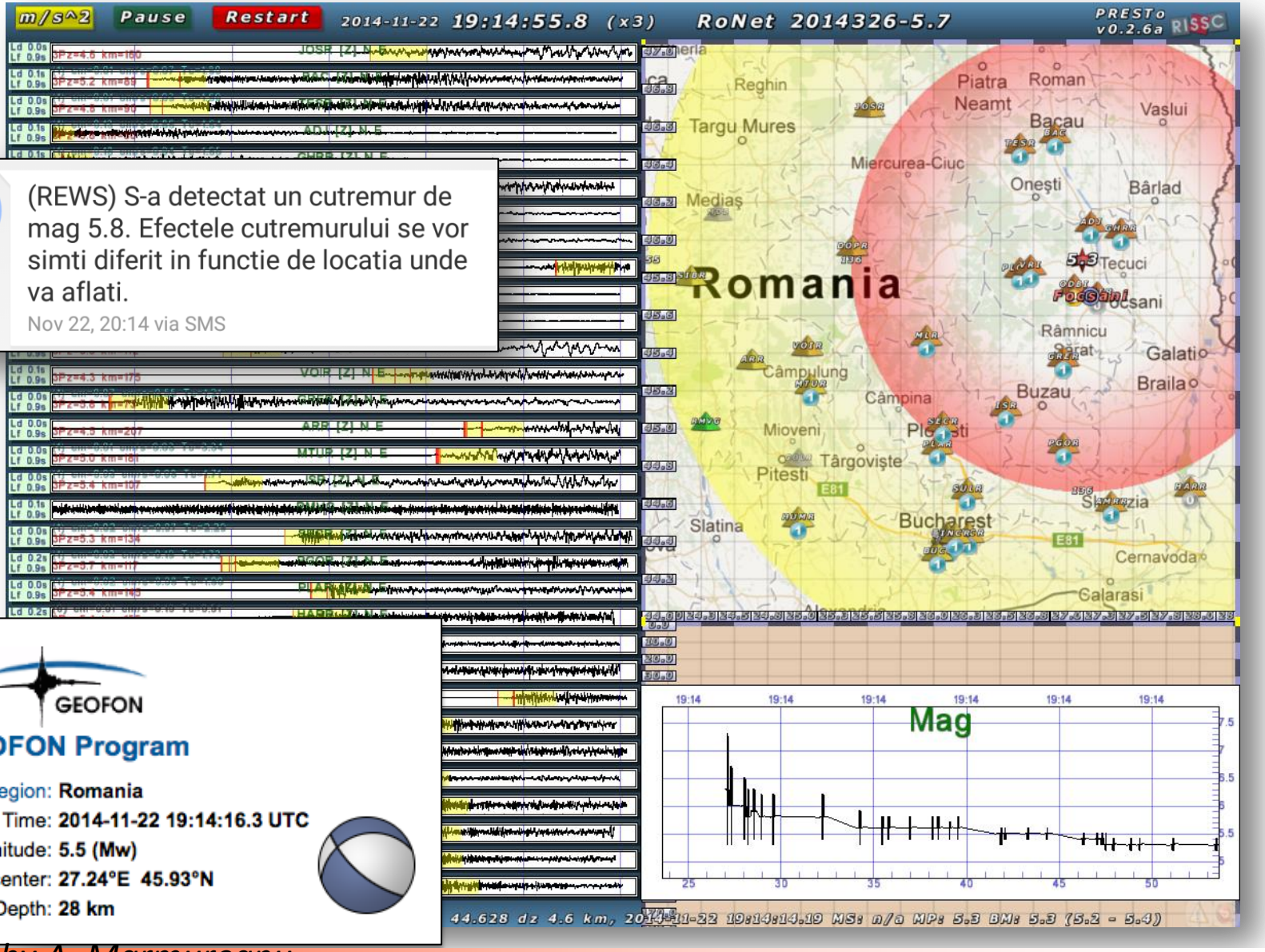
SMS
EMAIL

Procedures to be followed in case of a large earthquake occurrence

EDUCATION!!!

by A. Marmureanu

22nd Nov 2014, Mw 5.5 Eqk - Correctly Characterized



(REWS) S-a detectat un cutremur de mag 5.8. Efectele cutremurului se vor simti diferit in functie de locatia unde va aflati.

Nov 22, 20:14 via SMS

GEOFON

GEOFON Program

F-E Region: **Romania**
Time: **2014-11-22 19:14:16.3 UTC**
Magnitude: **5.5 (Mw)**
Epicenter: **27.24°E 45.93°N**
Depth: **28 km**

by A. Marmureanu

EEW in Operation: Romania – Current End Users

Public alerts not available or planned (limitation in communication infrastructure)

Nuclear Research Institute, Bucharest

Nuclear source used for sterilisation is **automatically secured** during an EEW alert

Pasajul Basarab Bridge, Bucharest

During an EEW alert, traffic light stops cars entering bridge

Vidaru Dam, Romania

Alert use to trigger data collection

Other End Users receive alerts only for *situational awareness*, incl.:

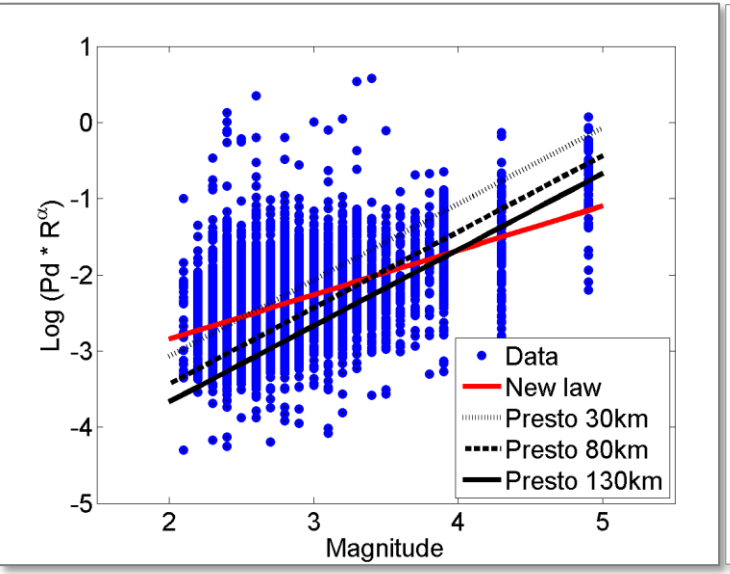
Nuclear Power Plants in Romania and Bulgaria

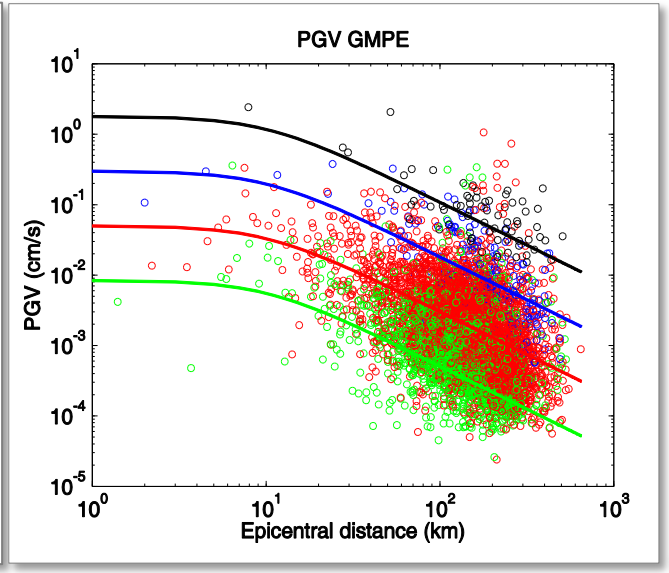
Emergency response institutions in Romania and Bulgaria

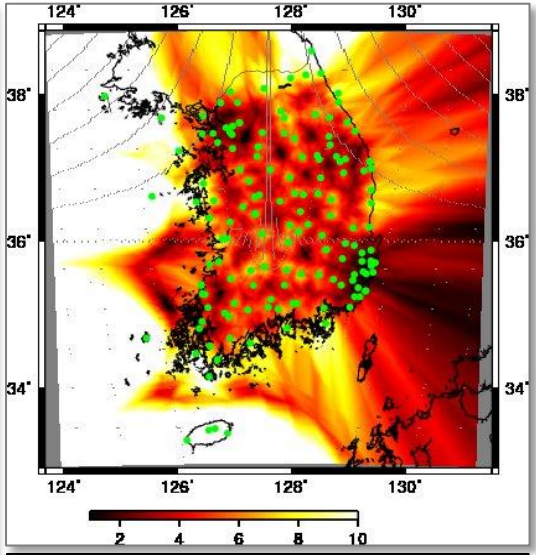
Application to South Korea

RISSC & KIGAM *cooperation started in the 2012*

- Database of ~200 earthquakes and **150 stations**
- M, hypocentral distance and Pd on 4s P-waves → **new regression law for magnitude**.
- PGD, PGA, PGV, epicentral distance → **new Ground Motion Prediction Equations**
- Theoretical analysis of the number of triggered stations for all possible events across Korea → **best parameterization of time windows for the earthquake detection**.



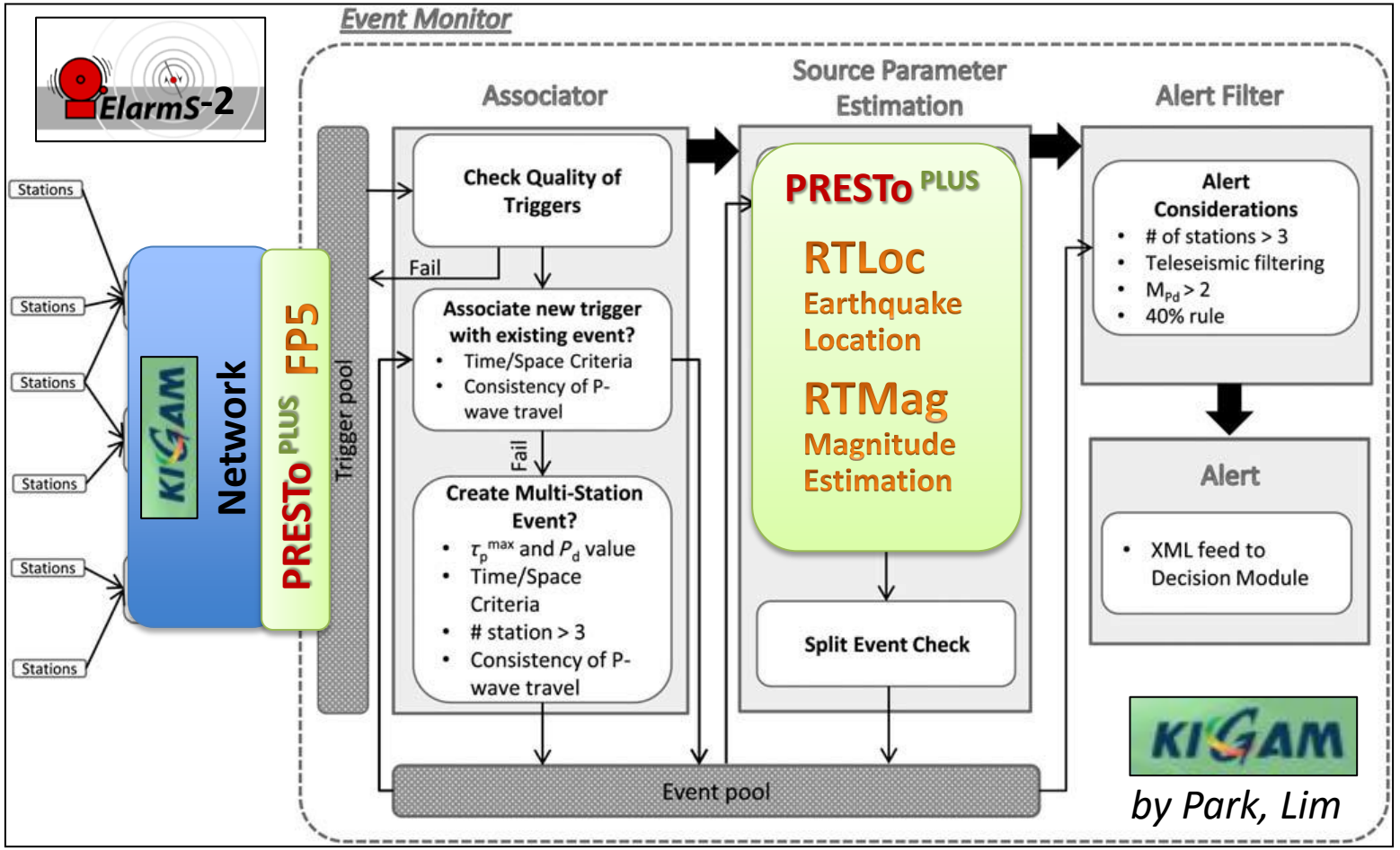




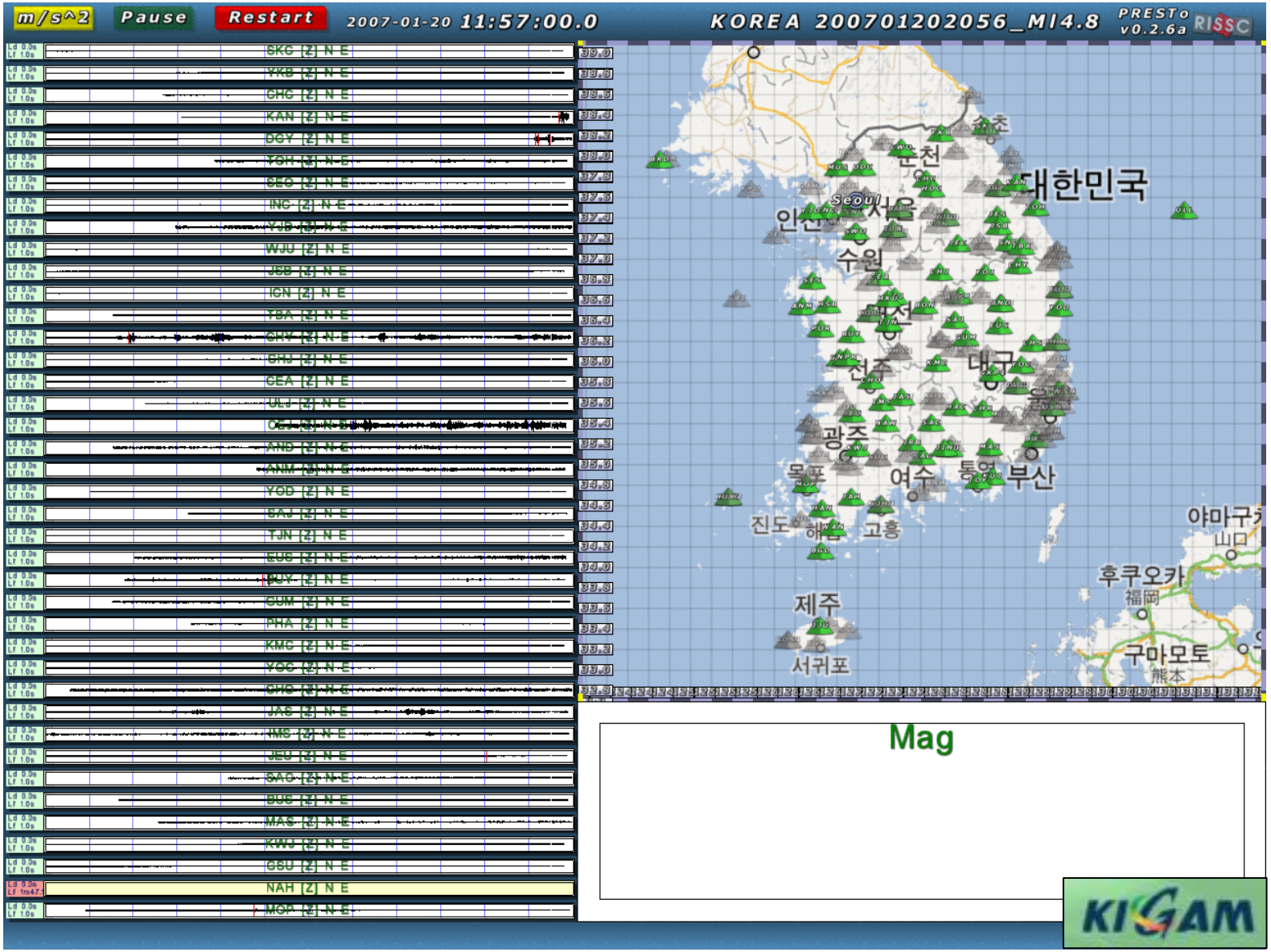
Time to detect picking at 8 stations from first detection

Application to South Korea

KIGAM's EEW Implementation: PRESTo algorithms (**FilterPicker, Threshold, RTLoc, RTMag**), as modules in the **Elarms-2** framework (**Elarms Binder**)

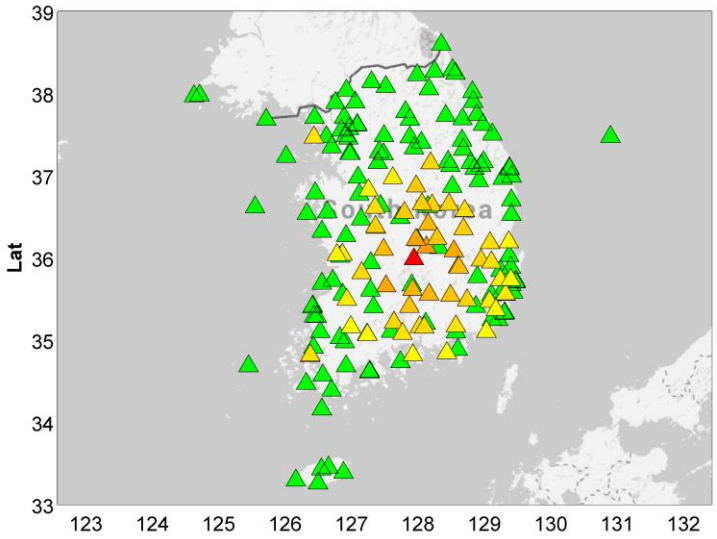


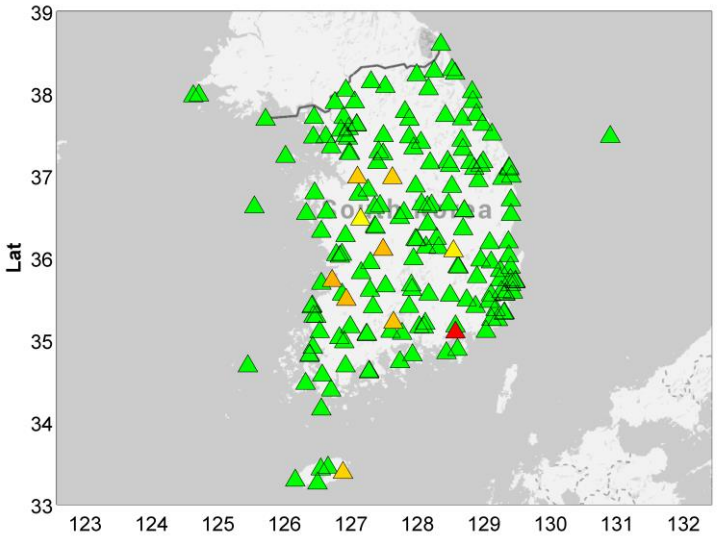
PRESTo PLUS - Performance on Korean Earthquakes Playback

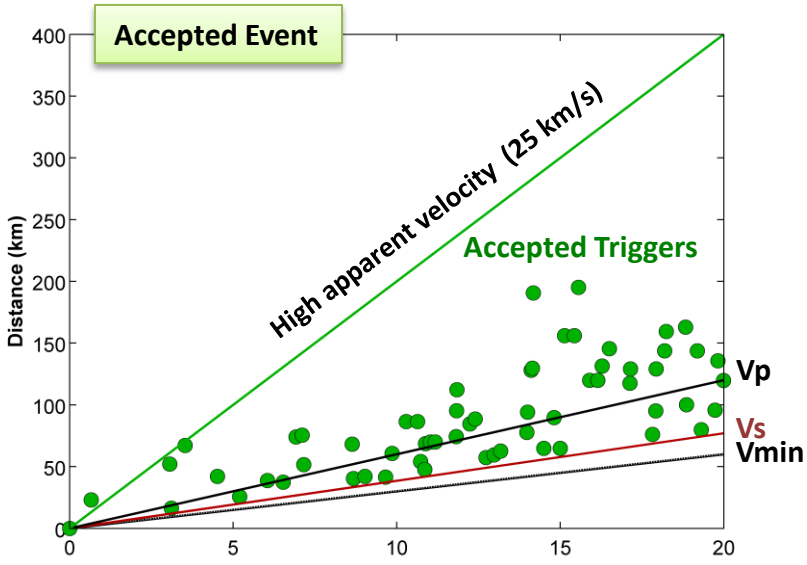


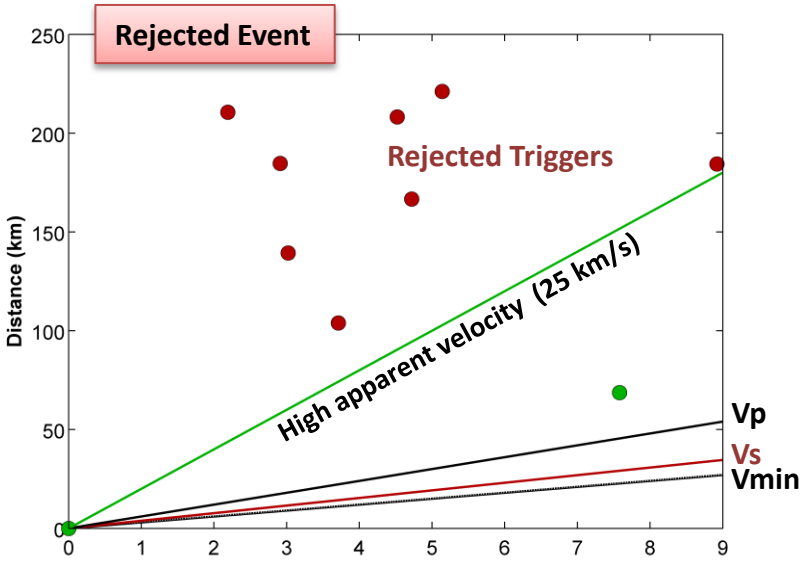
Application to South Korea

new association criteria for large networks are under test
(similar to the one of Elarms-2)









Application to The Trans-National Network in the South-Eastern Alps (NE Italy, Austria, Slovenia)

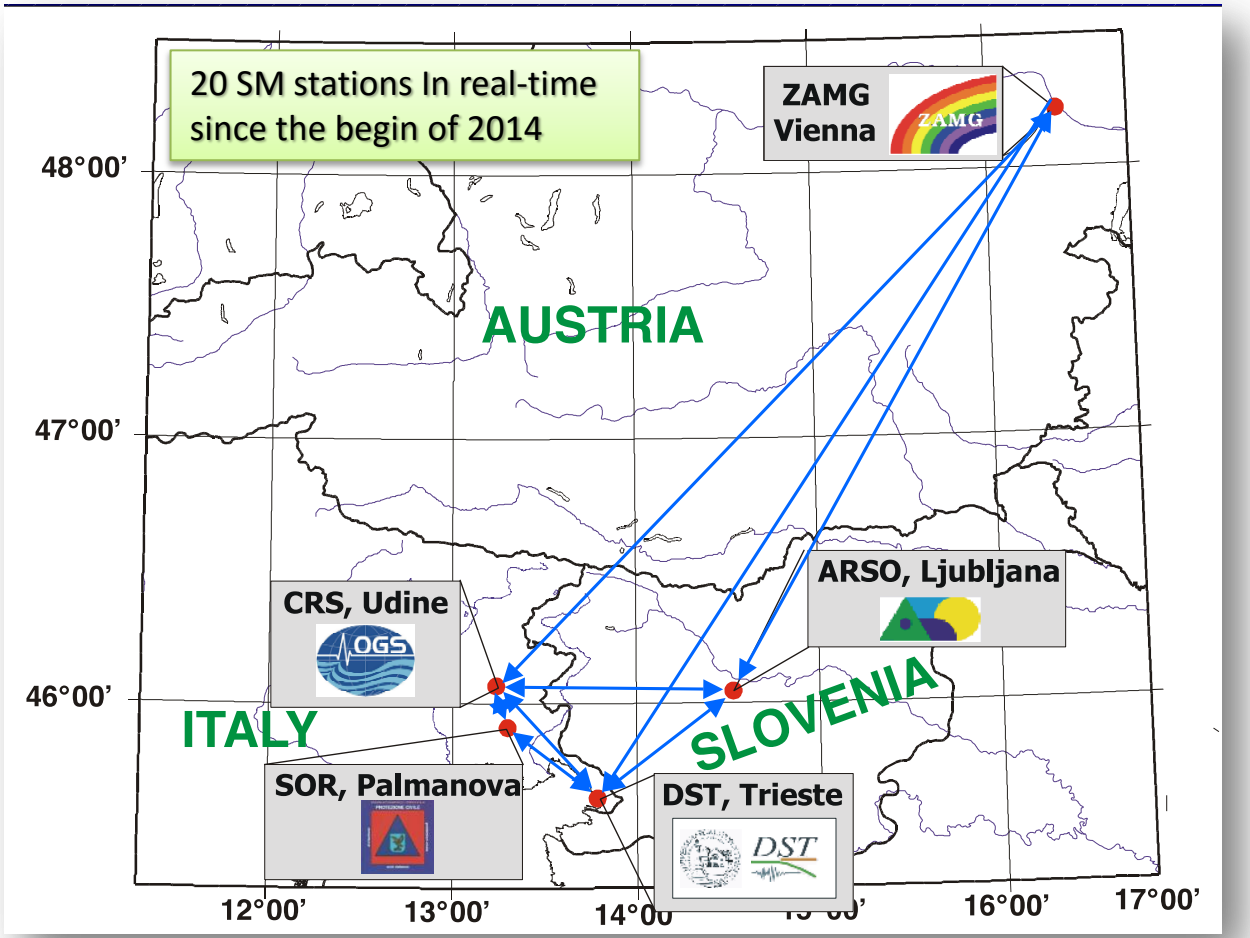
CE³RN – Central Eastern Europe Earthquake Research Network

ISTITUTO NAZIONALE DI OCEANOGRAFIA E DI GEOFISICA SPERIMENTALE

DST

AGENCIJA RS ZA OKOLJE

ZAMG
Zentralanstalt für Meteorologie und Geodynamik



from Bragato et al (2011)

Application to The Trans-National Network in the South-Eastern Alps (NE Italy, Austria, Slovenia)

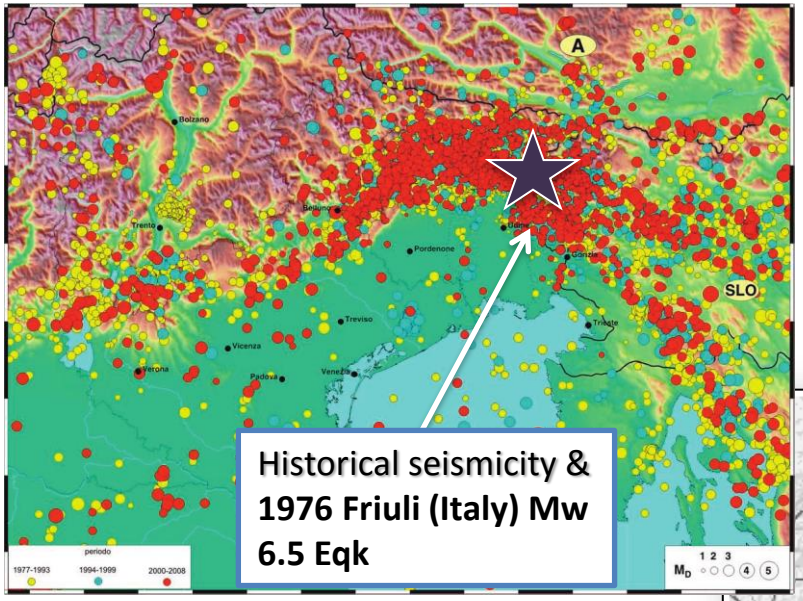
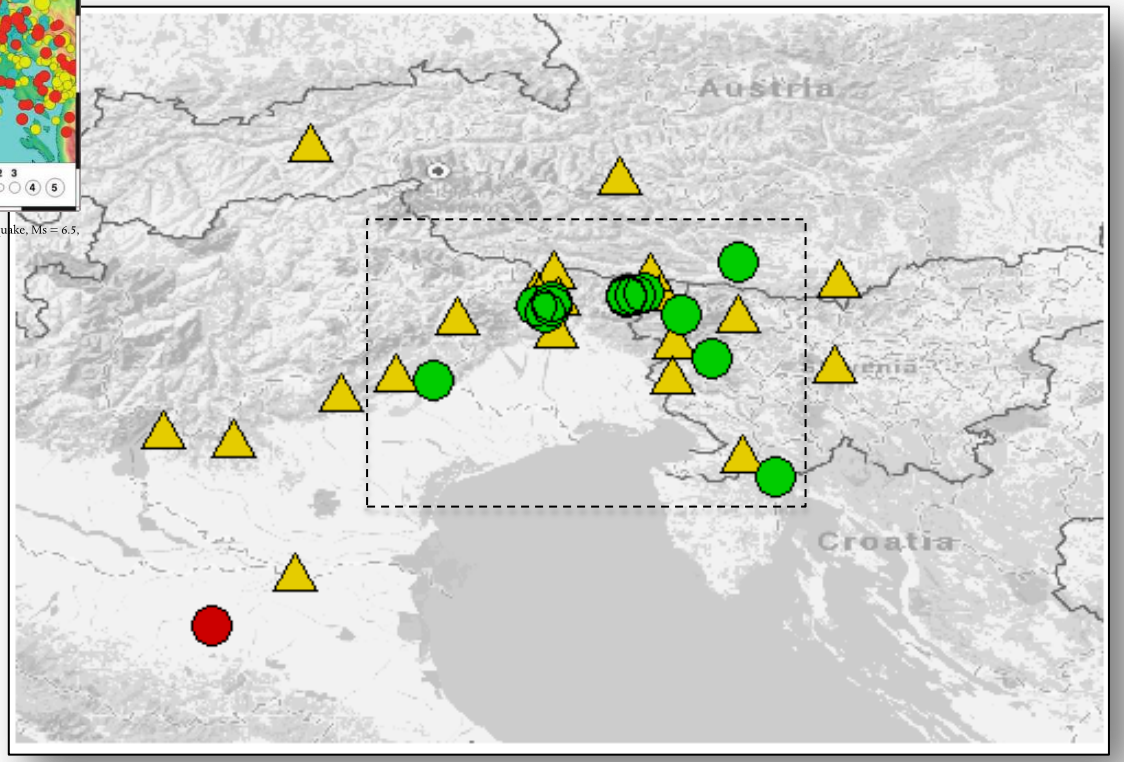


Figure 1. Seismicity of north-eastern Italy recorded at the OGS-CRS between 1977 and 2008 (courtesy of S. Urban). The 1976 Friuli earthquake, Ms = 6.5, is the largest recorded to date in the area.

The Real-time Experimentation

From May 2014 to May 2015,
15 Alerts sent (1 False event)

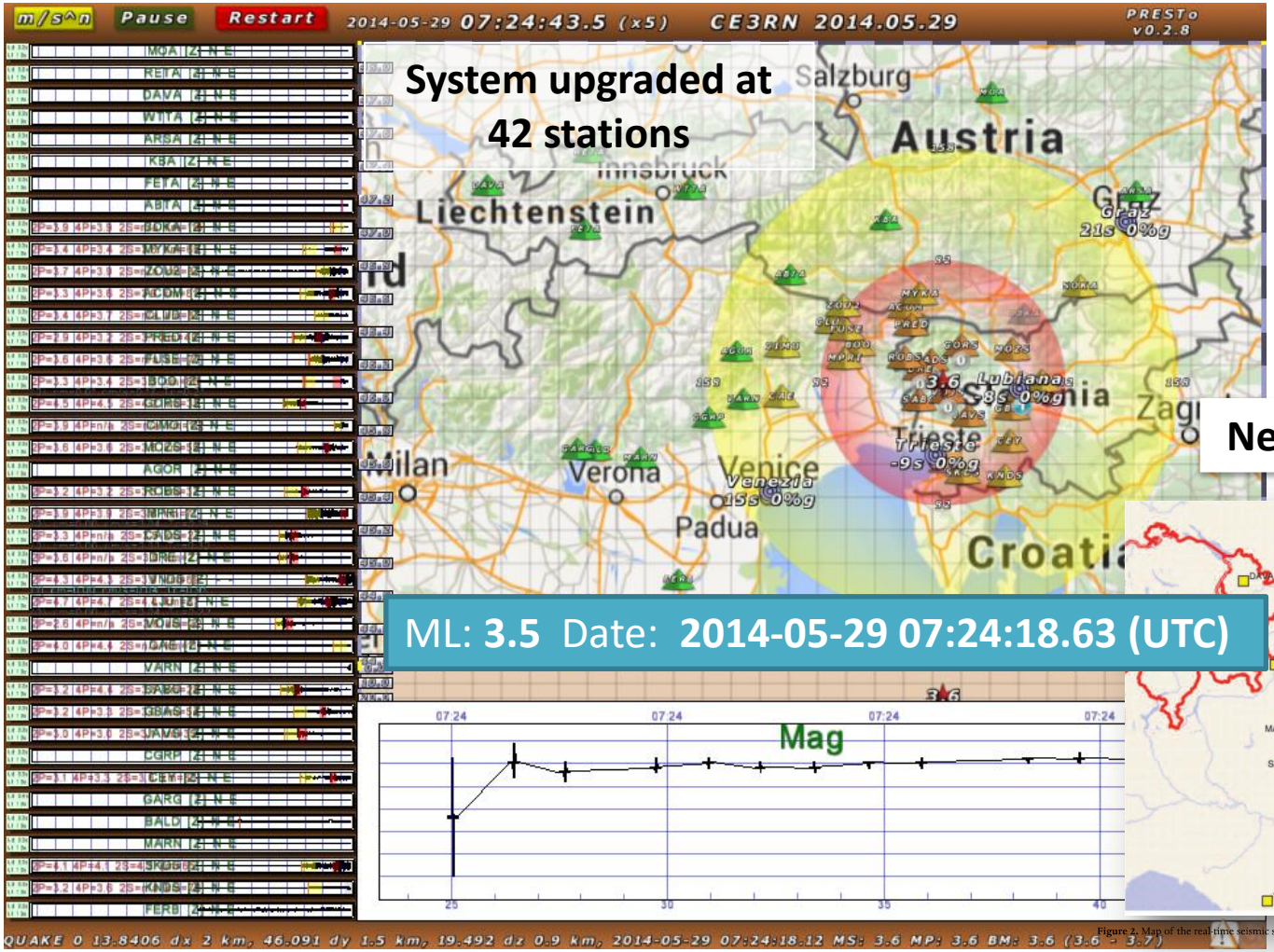


The EEWS is efficient with respect to earthquakes that occur nearby the area with higher station density.

An improve-ment in the system is necessary to cope with events occurring out of the network, and in general where it has a lower station density.

Application to The Trans-National Network in the South-Eastern Alps (NE Italy, Austria, Slovenia)

PRESTO^{PLUS} (v.0.2.8) ACCELEROMETERS + VELOCIMETERS

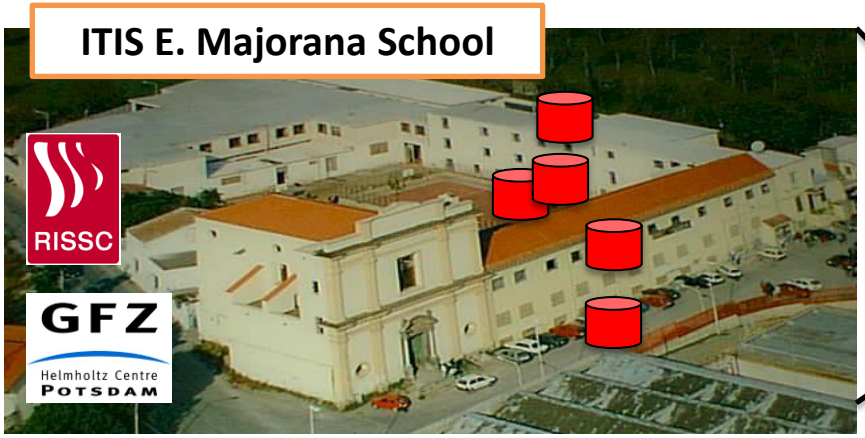


Alert released 10 seconds after the first P arrival detection

Next step: ~ 100 stations

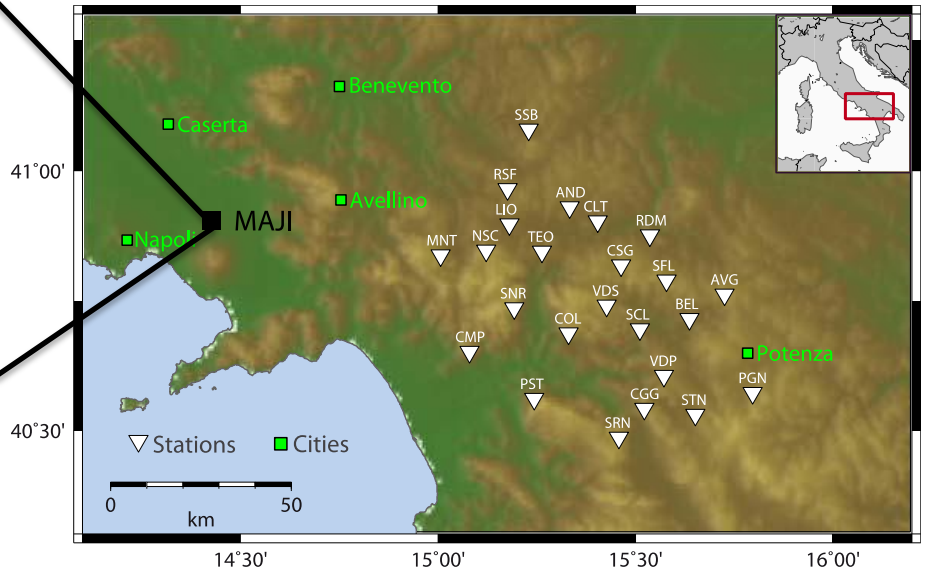
Figure 2. Map of the real-time seismic stations of the OGS-CRS.

PRESTo @ School – test site in southern Italy



5 strong motion stations

Students, about 950 (14-19 years old)
Staff, about 150



Regional EEW: the school station is a node of the regional seismic network, sending to the PRESTo[Plus] first P-wave arrival time and Peak Displacement. Hence, earthquake location and magnitude can be estimated and peak ground-motion at the target site can be predicted.

On-site EEW: the school node is ALSO a stand- alone EEW system, providing a local alert level based on the local measurement of P-peak displacement (Pd) and predominant period (□c)

PRESTo @ School – test site in southern Italy

PRESTo*Plus*

Regional **On-Site**

ALARM DEST:T_ING QID:365 SEQ:0 PGA:0.0118153
PGAer:0.00997635 PGV:0.000263345 PGVer:0.000198163
SECS:30.81 M:2.2 Mmin:1.6 Mmax:2.8 SumPd:-1.#INF
SumLgPd:-1.#INF SumTc:-1.#INF SumLgTc:-1.#INF STA:0
Rep:143.632 LON:15.7087 Xer:6.4 LAT:40.2468 Yer:4.3
DEP:18.344 Zer:11.4 Ot0:2014-09-24 15:39:17.50

Regional: PGV (cm/s) Prediction @ Target	< 0.2	> 0.2 & < 6.1	> 6.1
On-Site: Alert Levels	0	1	2 & 3
Sentinel Alert Levels	SILENT	LOW	HIGH

EEW SENTINEL

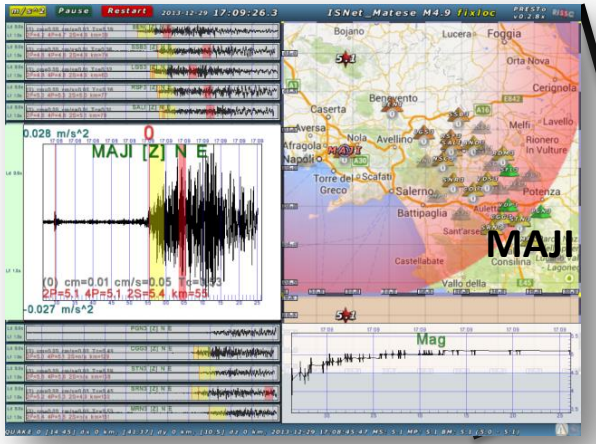
ACTIONS

The performance of the EEW system plus a ‘EEW Sentinel’ has been tested by the realization of off-line runs of the algorithm on the existing earthquake waveform data (i.e. playbacks).

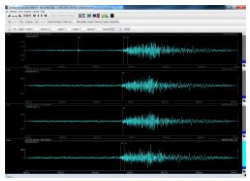
PRESTo @ School – test site in southern Italy

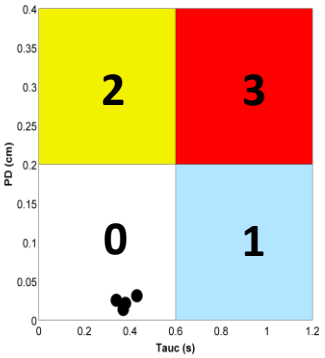
Integrated EEWS alert: the case of the ML4.9, 2013 Matese earthquake

Regional



On-site EEW





Alert level confirmed on-site

SILENT
Green Light
No Siren

Weak motion

2013-12-29 17:08:45 — T_0 Origin Time

Detection Time

17:08:56 — 1° Alert Sent to Target

17:08:57 — 2° Alert Sent to Target

17:08:58 — 3° Alert Sent to Target

17:08:59

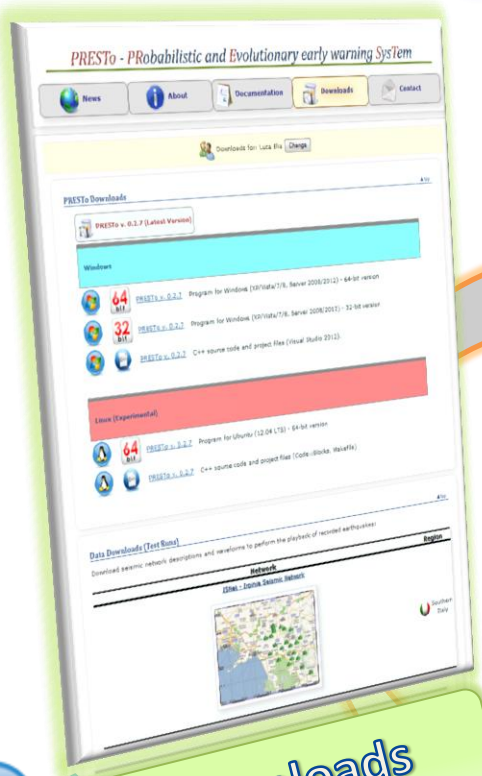
time

Lead Time: 7s
M:4,3
Mmin:3,9 Mmax:4,6
PGV: 0,09 cm/s

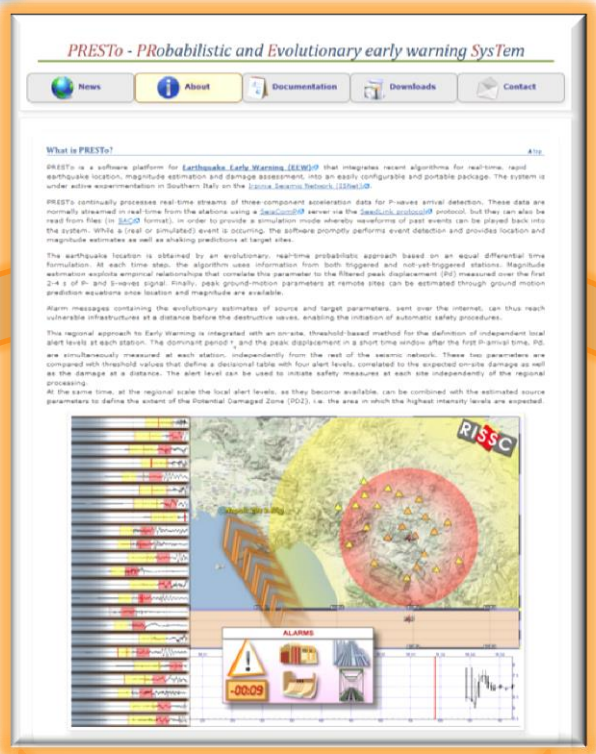
Lead Time: 6s
M:4,5
Mmin:4,3 Mmax:4,8
PGV: 0,13 cm/s

Lead Time: 4s
M:4,7
Mmin:4,5 Mmax:4,9
PGV: 0,19 cm/s

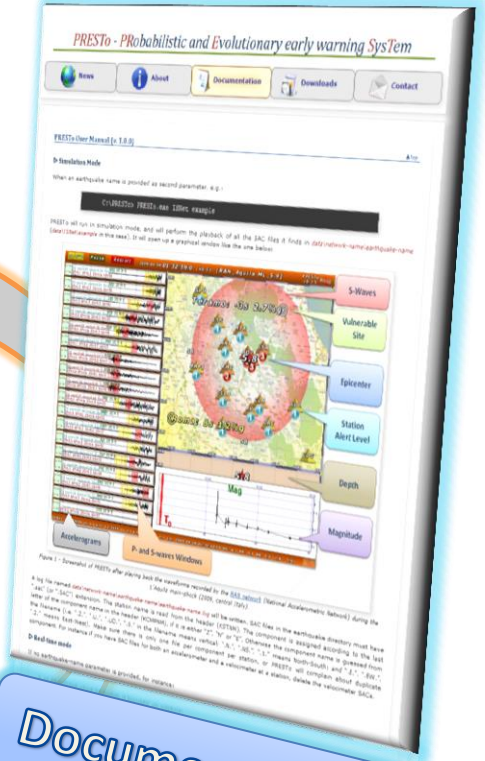
http:// prestoews .org



Downloads



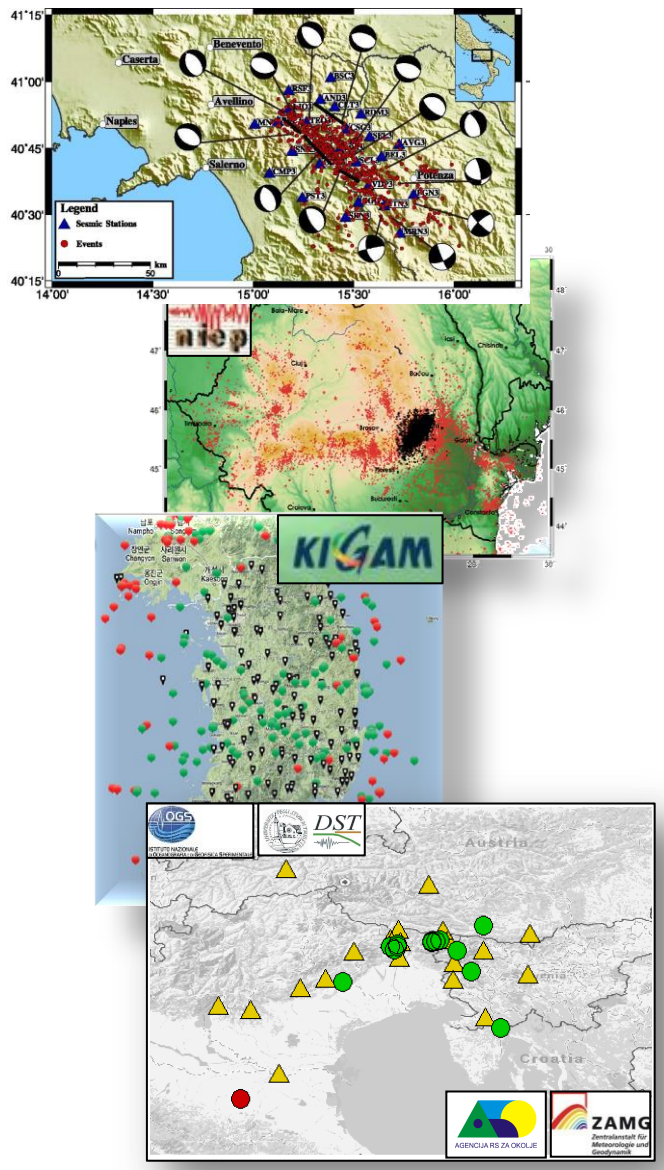
PRESTo distribution



Documentation

Thanks for your attention!

Conclusions



- Possibility to integrate multiple EEW systems
  - ➢ system modularity & flexibility
- Deep earthquakes , regional attenuation
  - ➢ Need of calibrating specific empirical scaling relationships
- High rate of false events in very dense networks
  - ➢ including apparent velocity and picking criteria
- Poor network coverage, unfavorable geometrical azimuthal coverage; bad communication system
  - ➢ technological update of the network; joint use of velocity and acceleration sensors
- EW@schools
  - ➢ Integrated regional/onsite EW system, link the EWS to a local control system.