Concept, Implementation and Testing of PRESTo: Real-time experimentation in Southern Italy and worldwide applications

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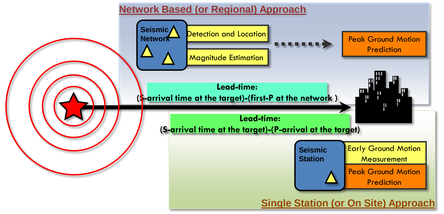
Introduction

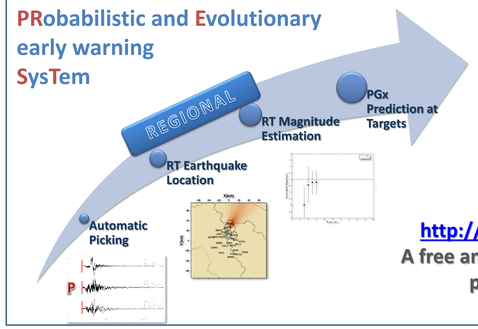


Earthquake early warning systems (EEWS) are Real-time, modern information systems that are able to provide rapid notification of the potential damaging effects of an ongoing earthquake, through the fast telemetry and processing of data from dense instrument arrays deployed in the source region of the event of concern (regional EEWS) or surrounding the target infrastructure (site-specific EEWS).

The PRESTo system

PRESTo[1] is a highly configurable platform for Earthquake Early Warning, that uses the "Regional" EW approach. It processes the real-time ground acceleration/velocity data streams from the seismic network to promptly provide the probabilistic and evolutionary estimates of location and magnitude of an earthquake while it is occurring, as well as the predicted maximum shaking over a broad region around the epicenter. Alarm messages can thus reach target sites before the S- and surface waves, enabling automatic safety actions for people and machinery at risk. The earthquake location is obtained by RTLoc method[2] that uses both triggered and not-yet-triggered stations at each time step. Magnitude is estimated using a Bayesian approach[3], from the peak displacement (Pd) measured in short (2-4 seconds) windows of P- and S-waves signal. Peak ground motion is estimated at target sites by GMPEs[4] using location and magnitude.

PRobabilistic and **E**volutionary early warning Sys**T**em

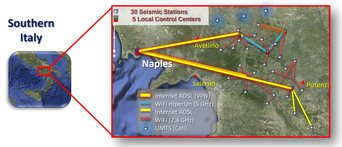


http://www.prestoews.org/

A free and open source software platform for EEW

System Performance in Italy

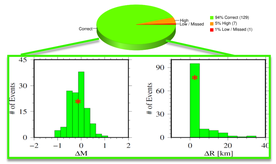
ISNet – Irpinia Seismic Network



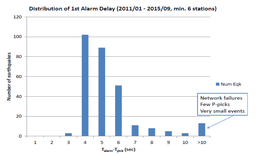
137 event with 2<M<3.7

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 : ~ 5 – 7 *km*

PRESTo Magnitude and Location Errors



PRESTo Time of the first alert

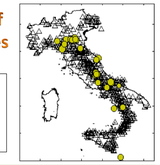


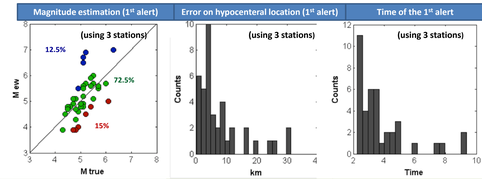
Using the 6 closest stations we experienced a reliable magnitude estimation in 94% of cases and a hypocentral location error smaller than 5 km in 76% of cases. The time of the first alert is 4-5 seconds on average, including computation and telemetry delays.

PRESTo Nation-Wide Performance Evaluation on RAN

Offline analysis of recent earthquakes

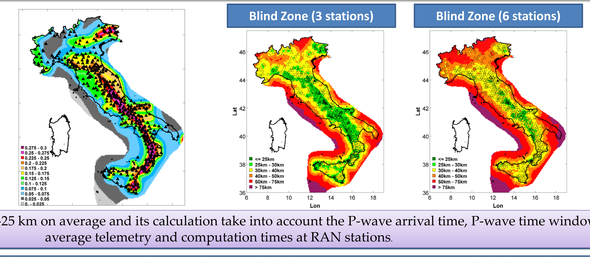
40 EQs, M_W>4.5, 2002-2013 from ITACA 2.0 (http://itaca.mi.ingv.it; Luzi et al., 2008; Pacor et al., 2011)





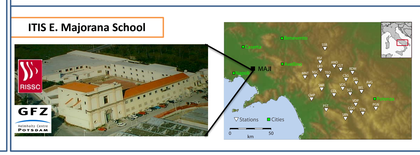
When a dense seismic network featuring real-time telecommunication is deployed in the fault area, PRESTo produces reliable estimates of the source parameters within 5-6 s from the first detected P-waves arrival.

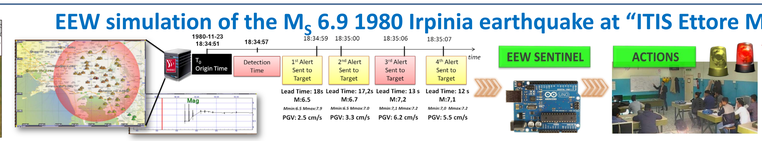
Analysis of reference earthquakes using Synthetic data



the Blind Zone radius is 20-25 km on average and its calculation take into account the P-wave arrival time, P-wave time window, average telemetry and computation times at RAN stations.

EEW simulation of the M_S 6.9 1980 Irpinia earthquake at "ITIS Ettore Majorana" School





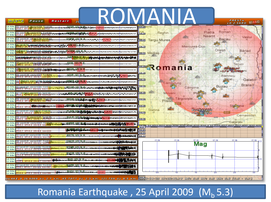
Time needed for going under the desk ≈ 4 s

Alert duration ≈ 150 s

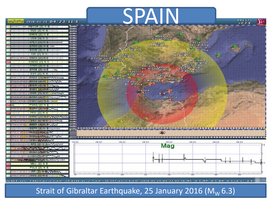
Alert level: moderate predicted PGV ≈ 5.5 cm that corresponds to I_{MM} of VI (strong perceived shaking/light potential damage)

Worldwide Performance

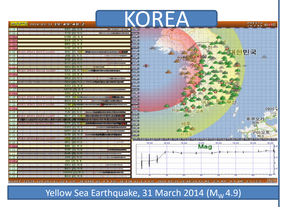
The PRESTo has been installed and tested in several countries worldwide in order to obtain relevant scientific indications and improve and optimize its algorithms.



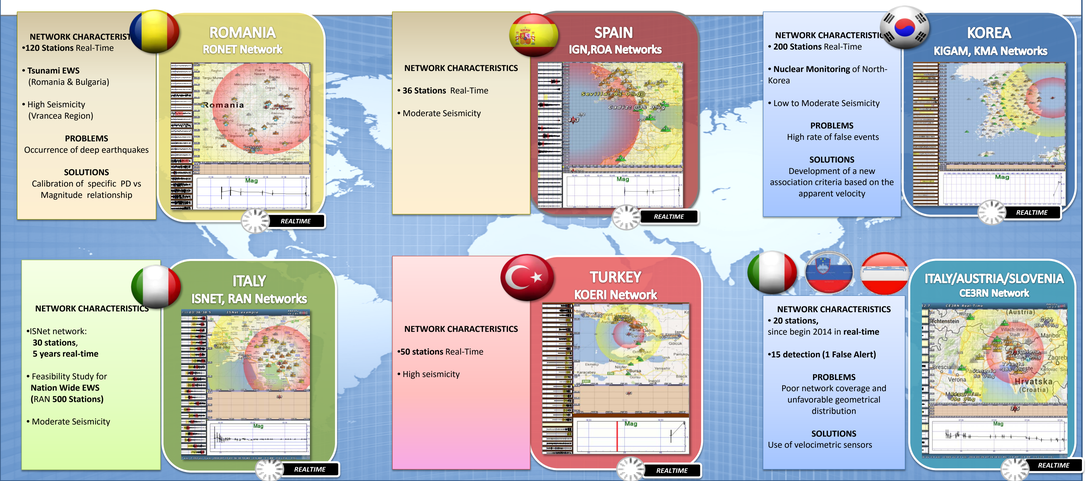
Romania Earthquake , 25 April 2009 (M_L 5.3)



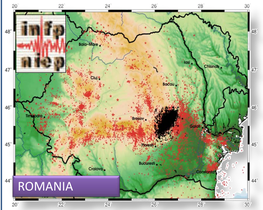
Strait of Gibraltar Earthquake, 25 January 2016 (M_W 6.3)



Yellow Sea Earthquake, 31 March 2014 (M_W 4.9)

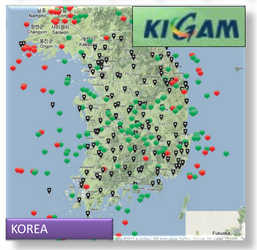


Feedback from the use of PRESTo



PROBLEMS:
Deep Earthquakes

SOLUTIONS:
•Need of calibrating specific empirical scaling relationships
•Possibility to integrate multiple EEWS



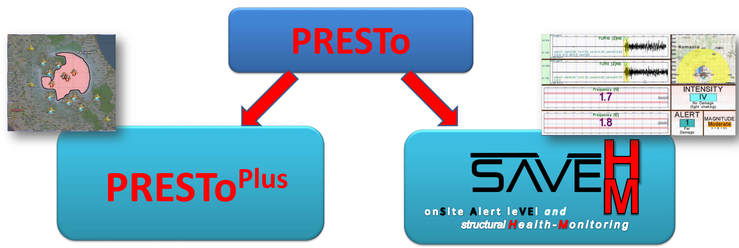
PROBLEMS:
High rate of false events in very dense network

SOLUTIONS:
•Real-Time apparent velocity analysis
•Adapted picking criteria

PROBLEMS:
•Poor network coverage
•Bad communication system and poor data quality

SOLUTIONS:
•Tecnological update of the network
•Use of velocity sensors

Perspectives



Starting from PRESTo methodologies, two new software are under development: SAVE and PRESTo^{Plus}. SAVE (on-Site Alert leVEl) is essentially a single-station, on-site EEW approach, while PRESTo^{Plus} combines the "Regional" and the "On-Site" EEWS approaches to obtain a real-time definition of the Potential Damage Zone Maps.

References

[1] Satriano, Elia *et al.* (2010). PRESTo, the earthquake early warning system for Southern Italy: Concepts, capabilities and future perspectives. *Soil Dyn Earthq Eng, doi 10.1016/j.soildyn.2010.06.008.*

[2] Satriano *et al.* (2008) Real Time Evolutionary Earthquake Location For Seismic Early Warning, *Bull.Seism. Soc. Am.*, 98, 1482-1494.

[3] Lancieri & Zollo (2008). Bayesian approach to the real-time estimation of magnitude from the early P and S wave displacement peaks. *J.Geophys. Res.* 113, doi:10.1029/2007JB005386.

[4] Akkar, Bommer (2007). Empirical prediction equations for peak ground velocity derived from strong-motion records from Europe and the Middle East. *Bull Seism Soc Am 97:511-530.*