THE EARTHQUAKE EARLY WARNING SYSTEM IN SOUTHERN ITALY: TECHNOLOGIES, METHODS AND PERFORMANCE EVALUATION

Aldo Zollo

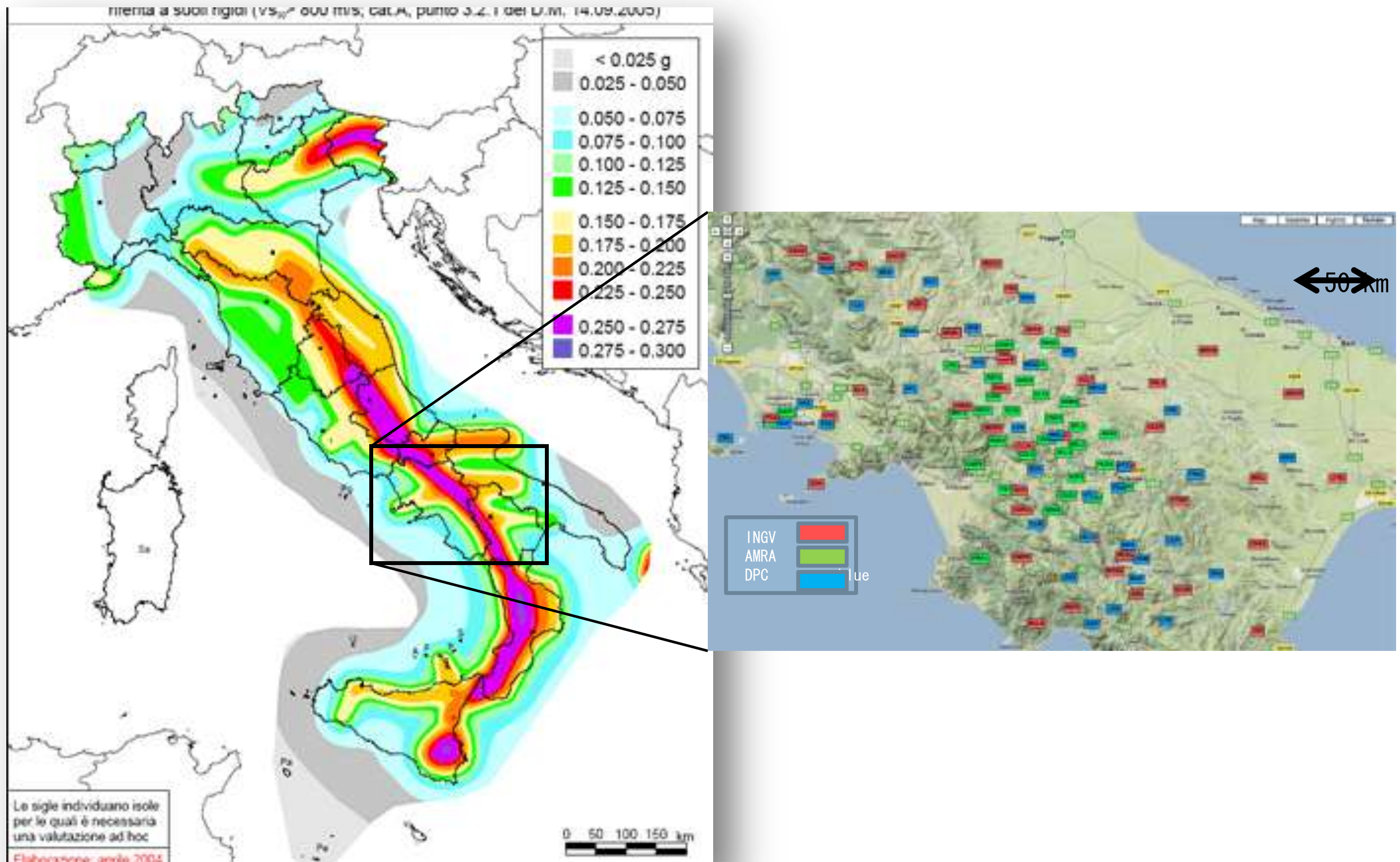
University of Naples "Federico II"

With the main contribution of:

G.Iannaccone, M.Lancieri, C. Satriano, G.Festa, C.Marti

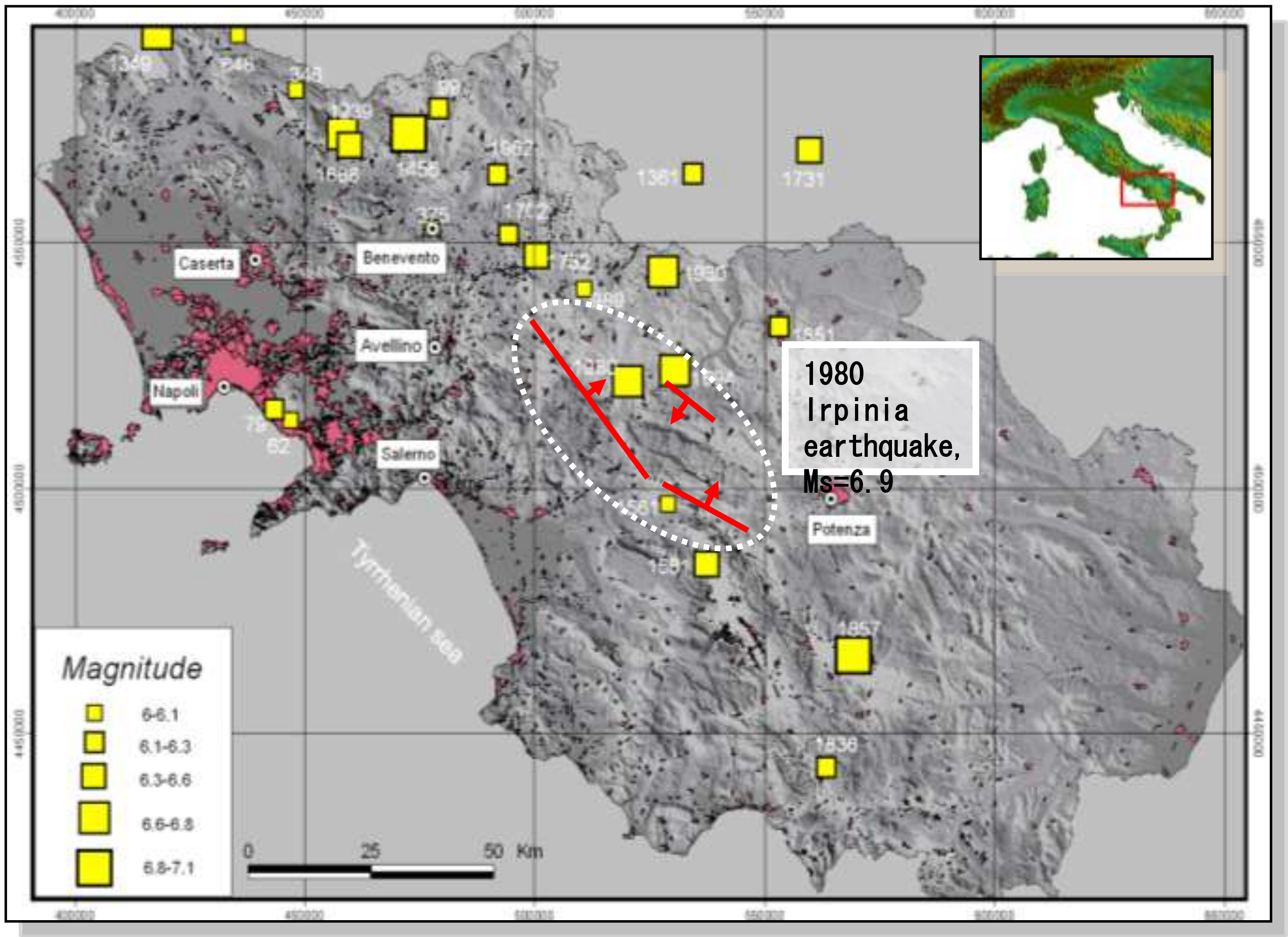
An EEW system in Southern Italy

A real-time seismic alert management system is under testing in southern Italy. It is based on a dense, wide dynamics seismic network monitoring one of the highest earthquake hazardous



Historical Earthquakes

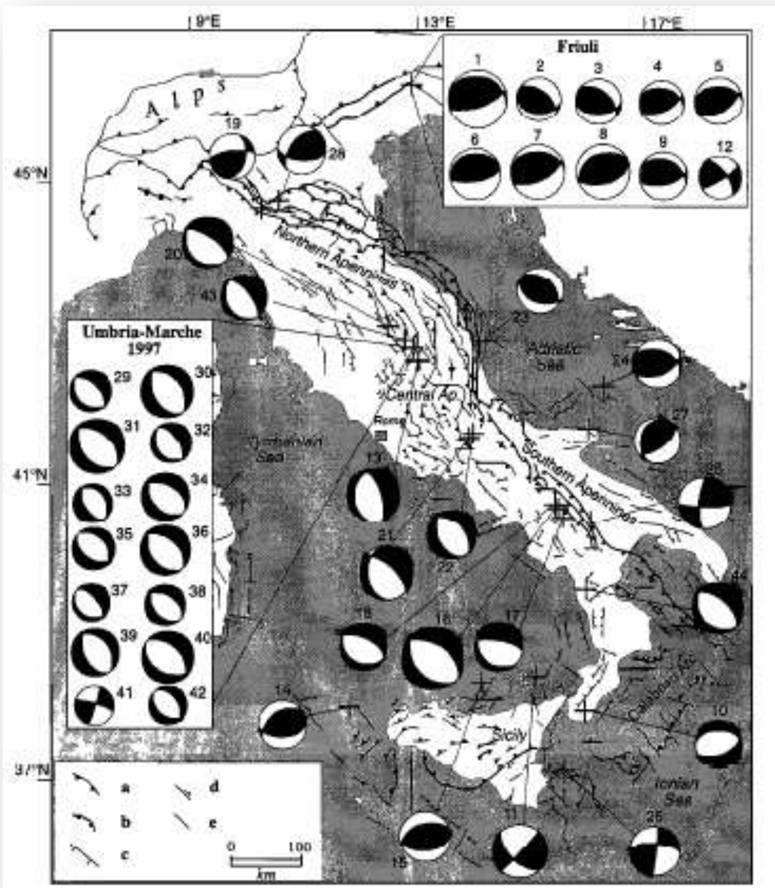
This region has experienced in the past several destructive events the most recent one, with magnitude 6.9, occurred in 1980, producing extended damaging and



Tectonic regime

Montone et al., JGR, 1999

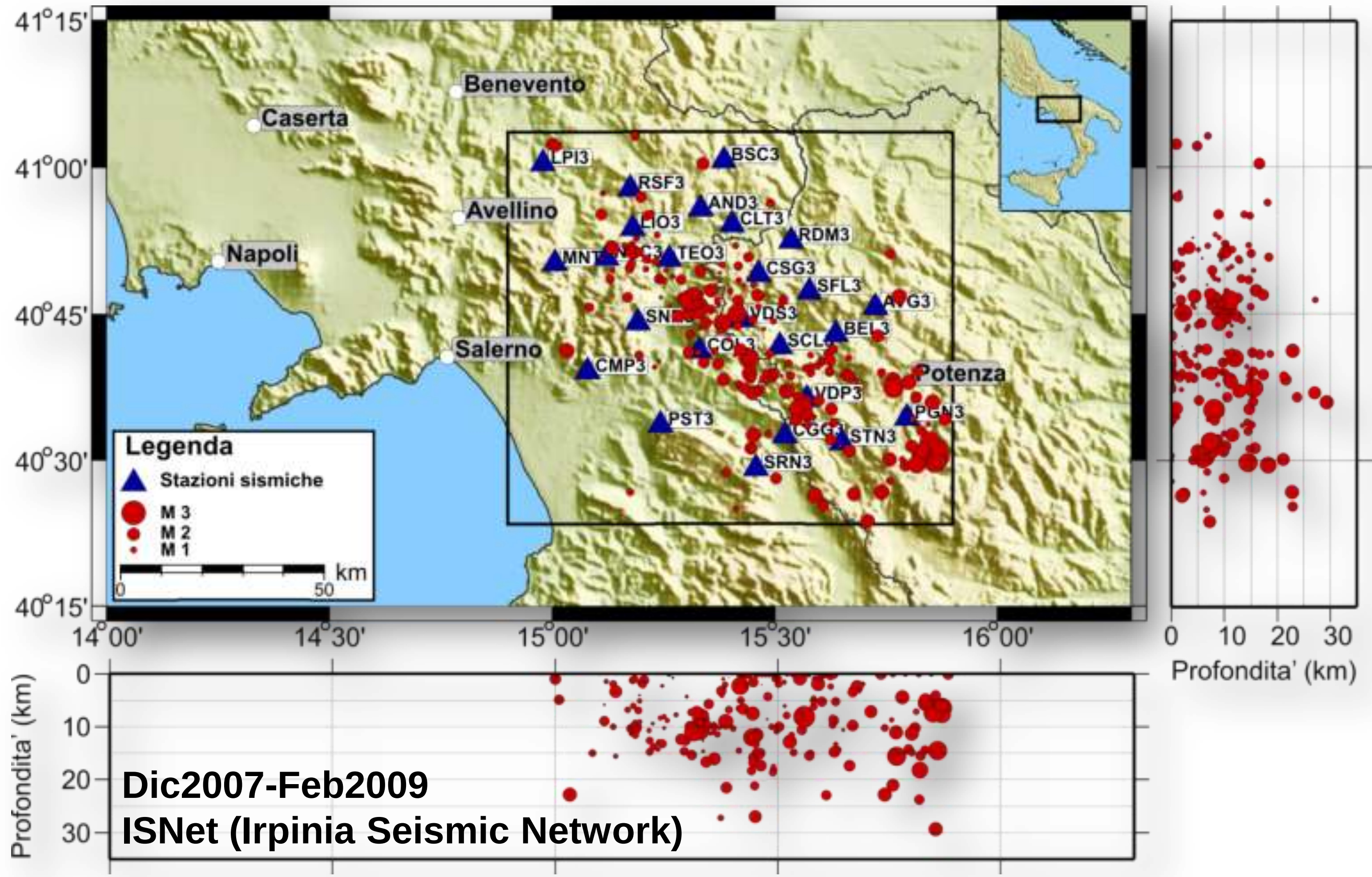
Focal mechanisms



Stress orientations

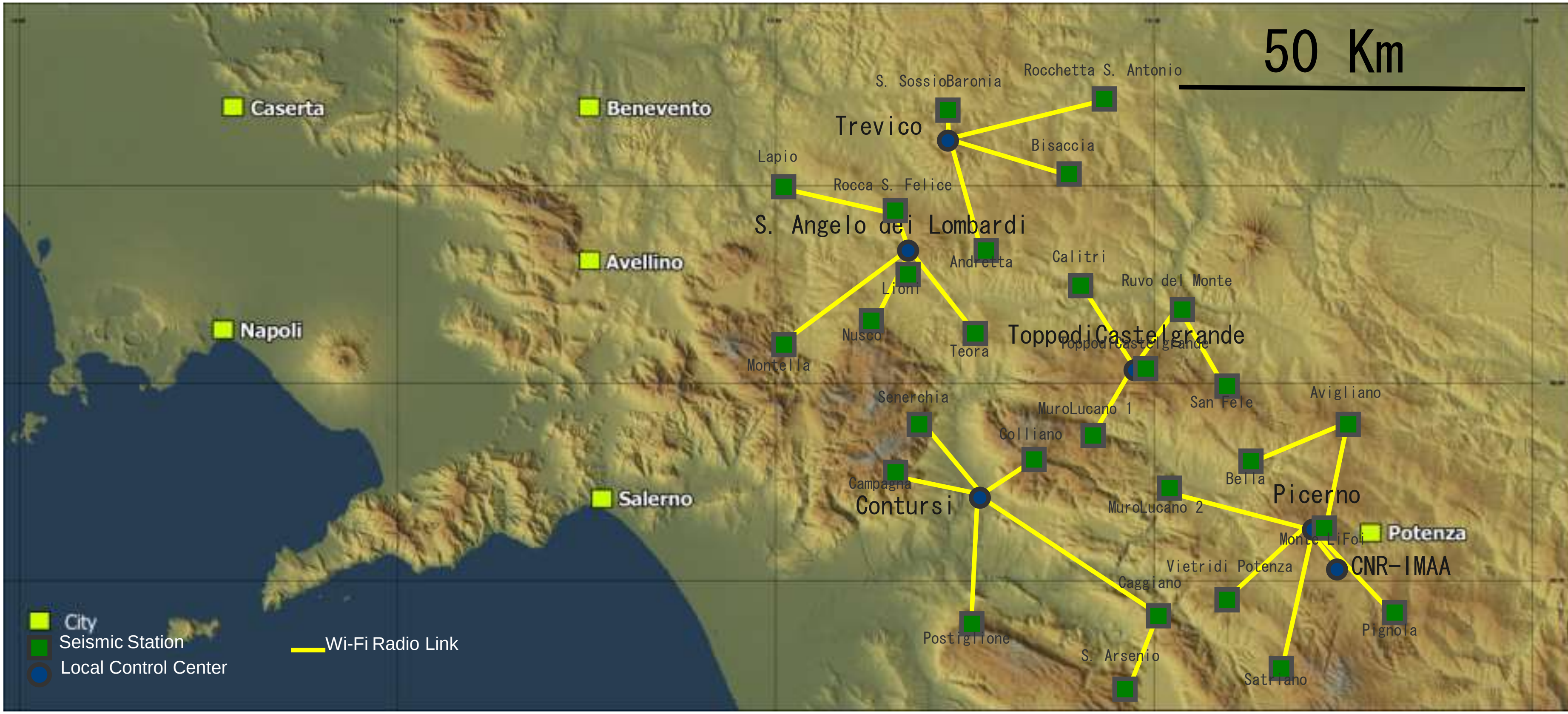
Present-day seismicity

The current low-magnitude seismicity occurs along the Apenninic belt, normal fault system 1980 earthquake fault system within the



The Irpinia Seismic Network (ISNet)

Seismic Stations and Local Control Centers



28 Sites

OSIRIS

CMG-5T

and

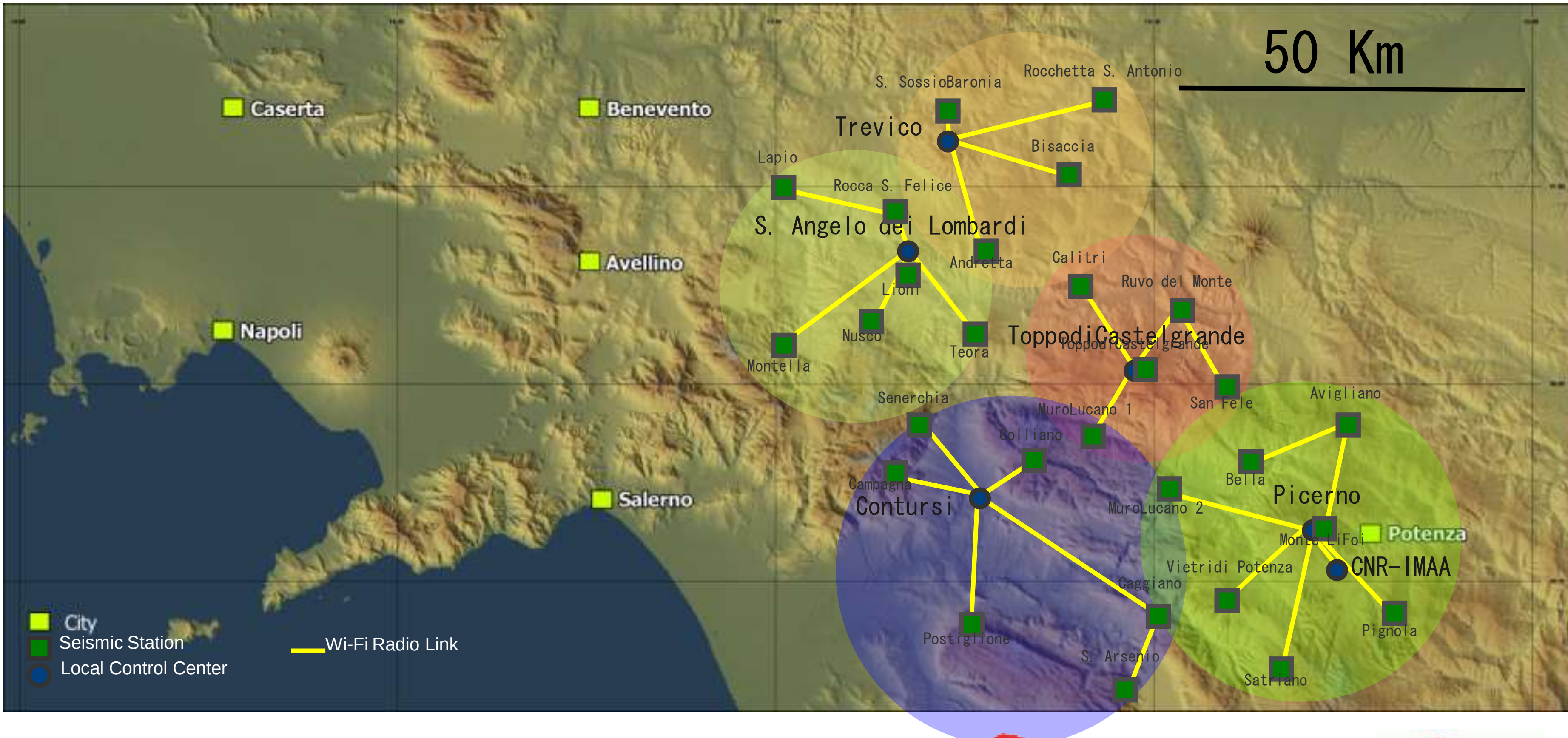
S13-J

or

Trillium 40S

The Irpinia Seismic Network (ISNet)

Local Control Centers: Virtual Sub-Networks



5 LCCs

HP Proliant DL140

debian

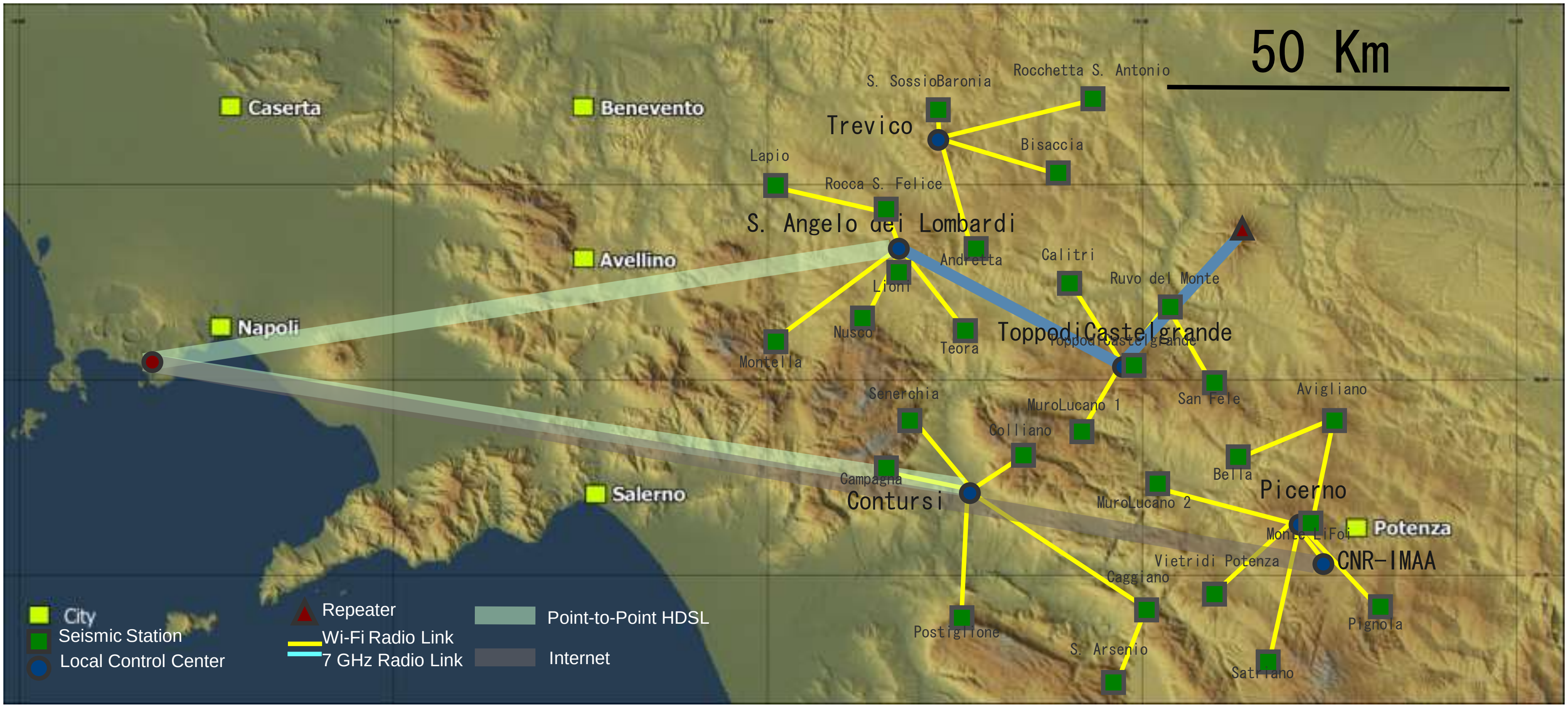
GFZ POTSDAM

SeisComP

Earthworm

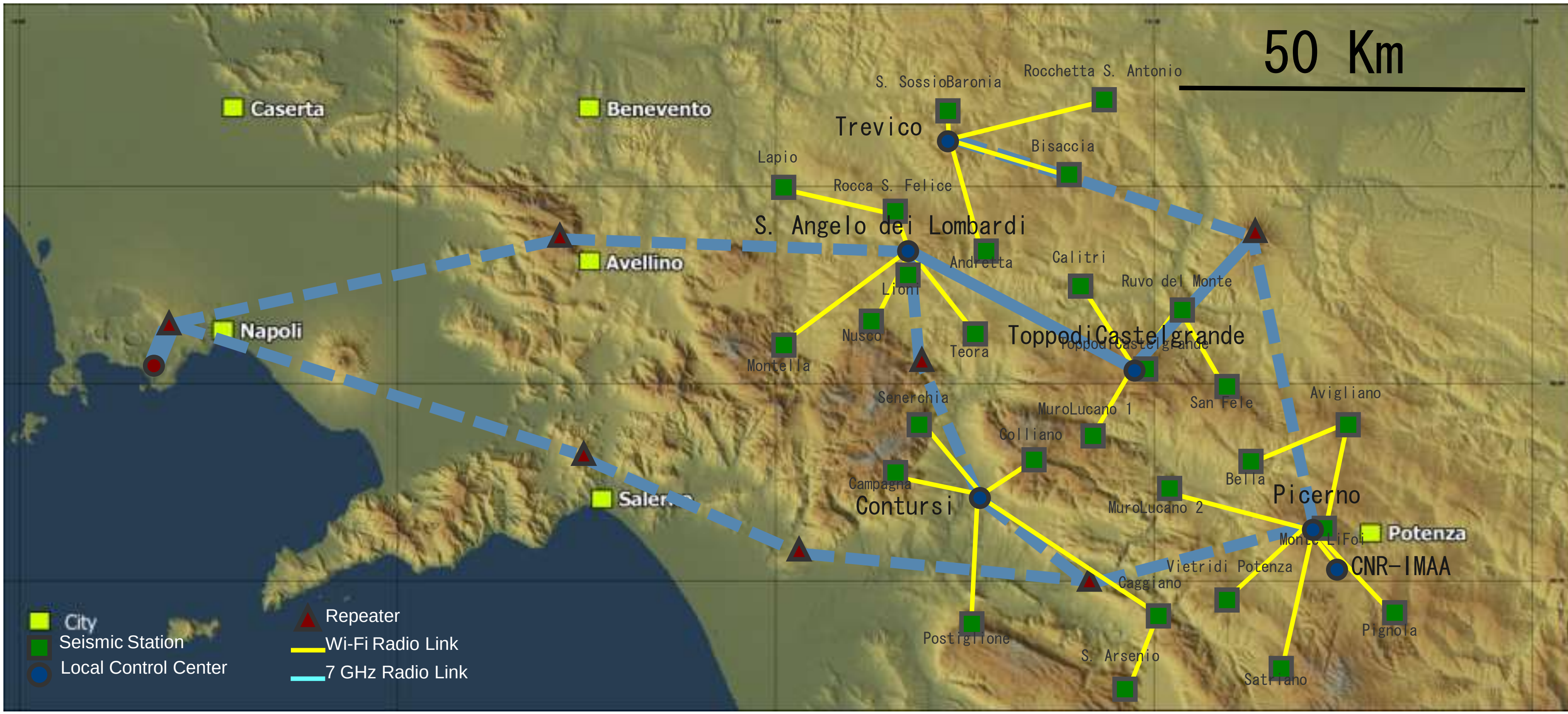
The Irpinia Seismic Network (ISNet)

Current Communication System: HDSL + Internet + Radio-Links



The Irpinia Seismic Network (ISNet)

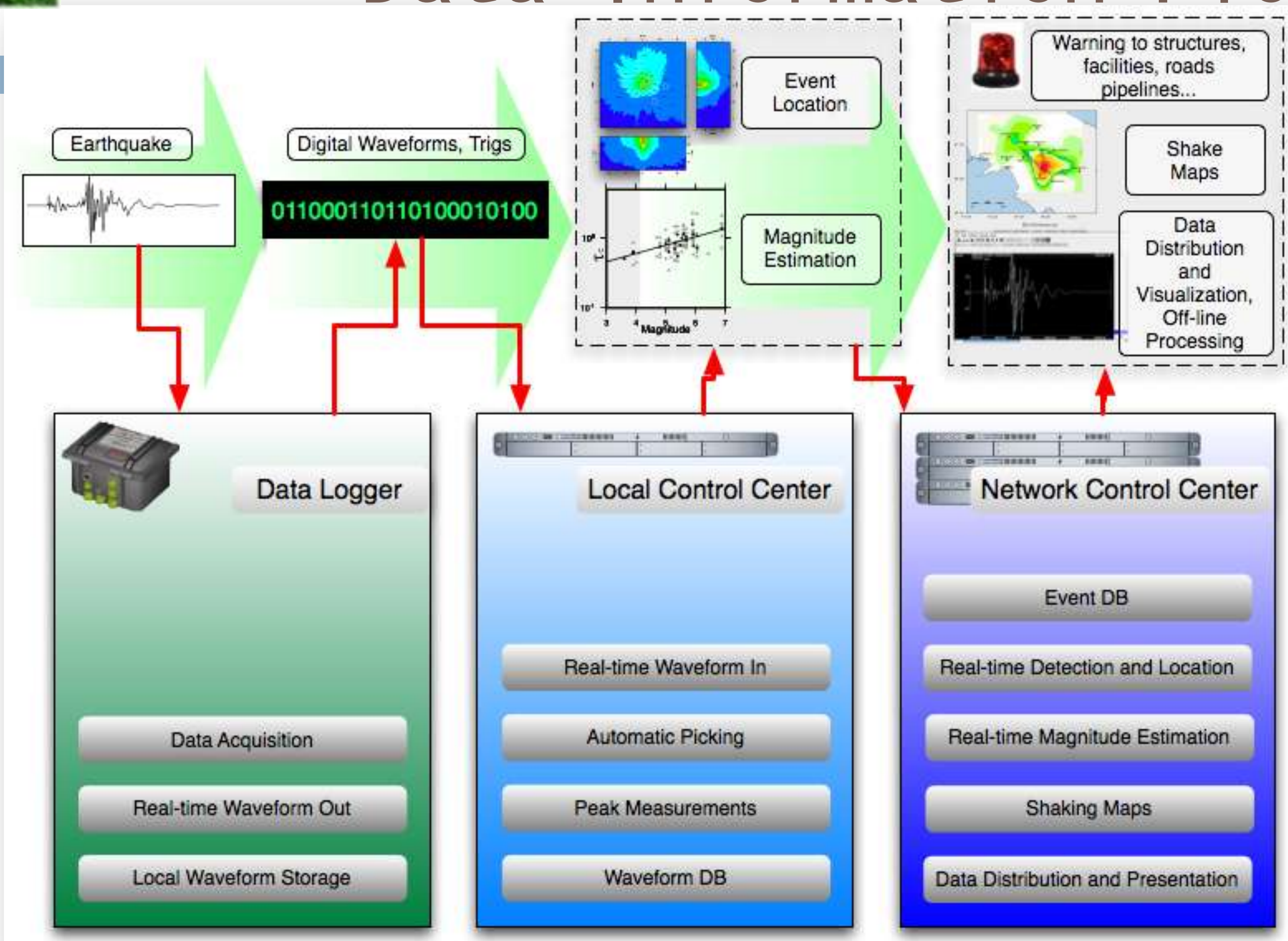
Planned Communication System: Fully Proprietary Radio-Links



Site conditioning

LEFT The seismic and data transmission equipments are housed in a 6x2 m shelter, with solar panels and batteries, that can telemetry to the network control center the environmental parameters (temperature, battery voltage level, disk memory state, …) through an independent GSM modem transmission.
RIGHT Local Control Center (LCC) are data-collector sites aimed at managing the real-time communication with sub-net nodes, pre-processing and exchanging data with other LCCs and the networc center in Naples.

Data Information Flow



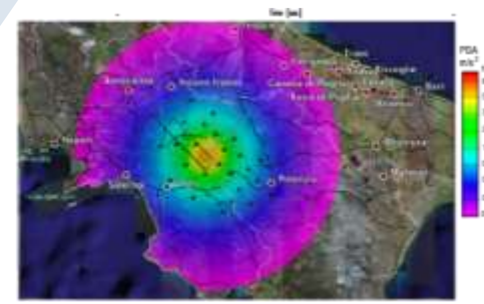
PRESTo

(Probabilistic & evolutionaRy Early warning SysTem)

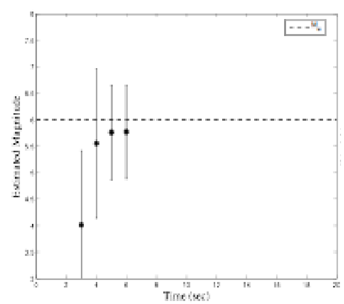
Automatic procedures for the probabilistic and evolutionary estimation of source parameters and prediction of ground motion shaking.

Visit the poster by Iannaccone et al.

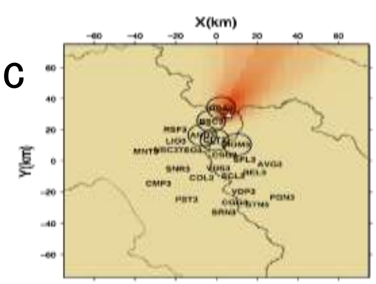
PGX prediction at the target sites



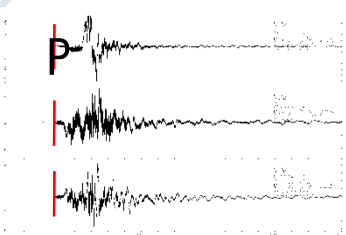
RT Magnitude estimation



RT Earthquake location

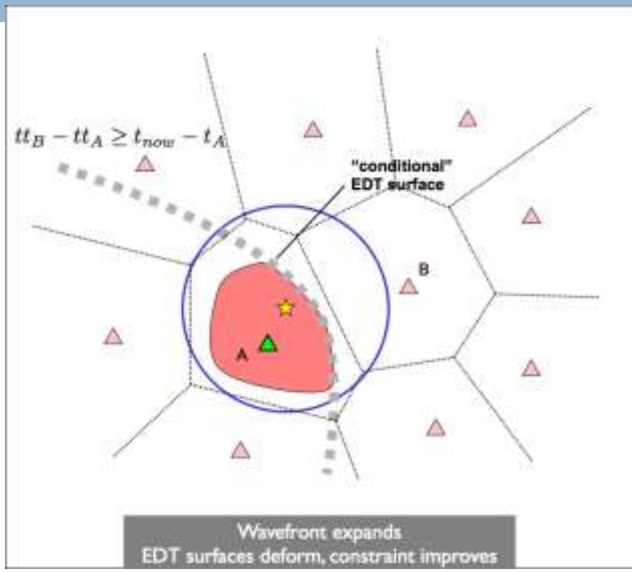


Automatic Picking

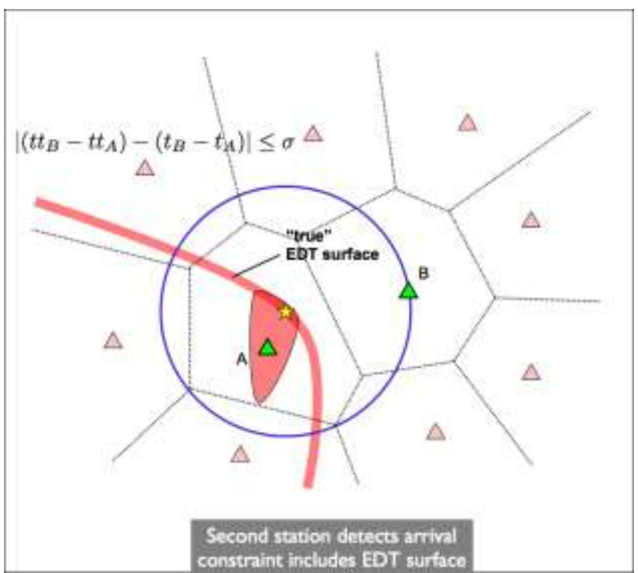


An integrated software platform for the real data processing and seismic alert

Real-time earthquake location



Wavefront expands
EDT surfaces deform, constraint improves

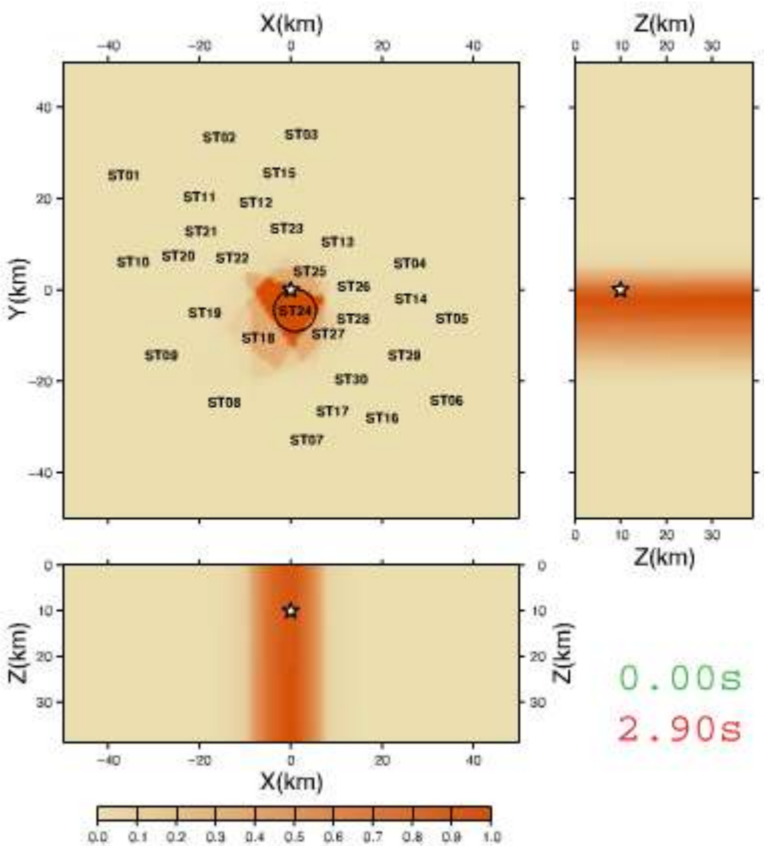


Second station detects arrival
constraint includes EDT surface

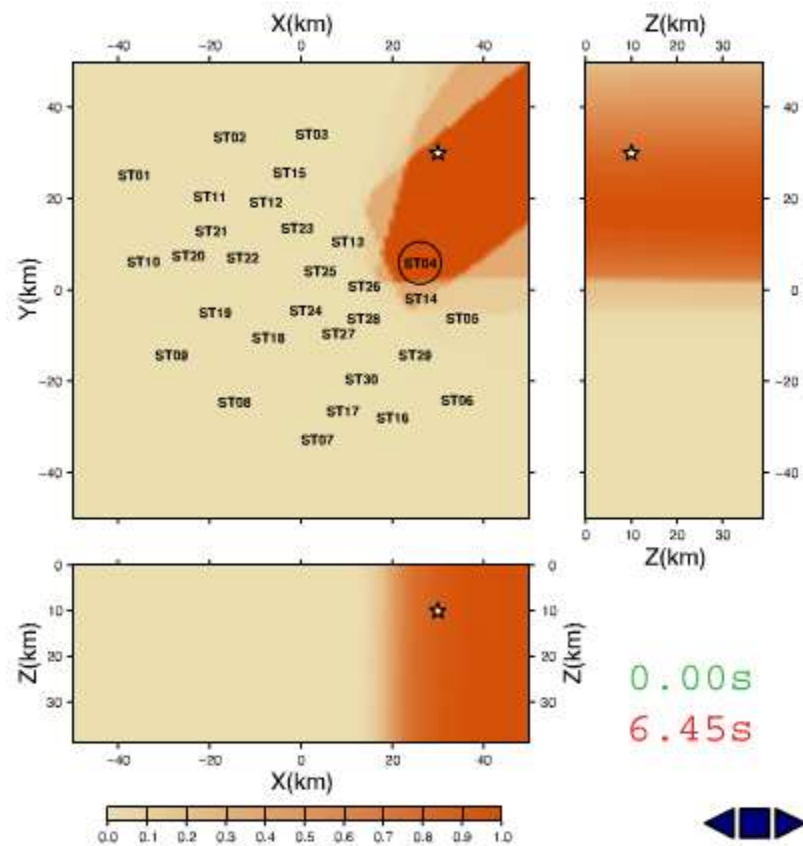
Basic concepts

- Information from the stations that have not yet recorded the event
- Tracing and intersections of the isocrone surfaces
- Probabilistic estimation of the earthquake location as a function of time (evolutionary

Synthetic Simulation



Earthquake location probability



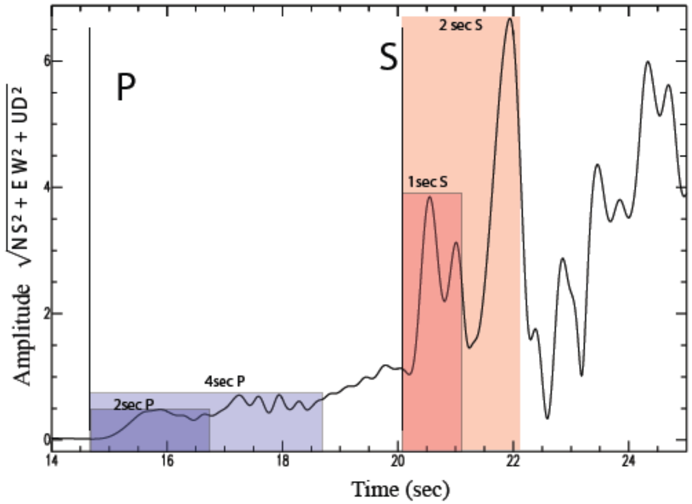
Earthquake location probability

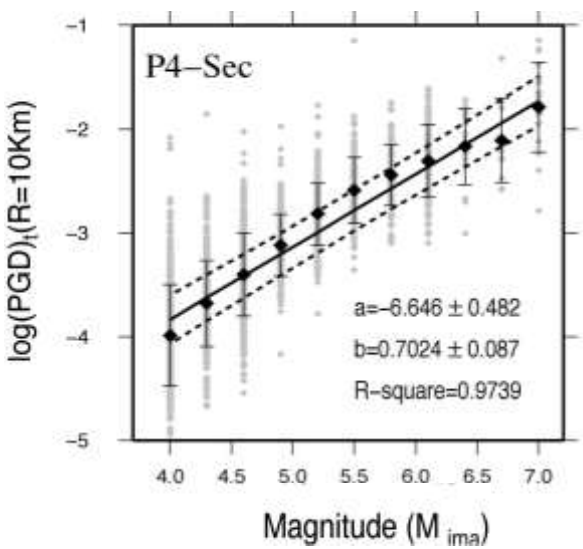
Seconds from first trigger

Seconds from earthquake Origin Time

Triggered stations

Real Time Magnitude





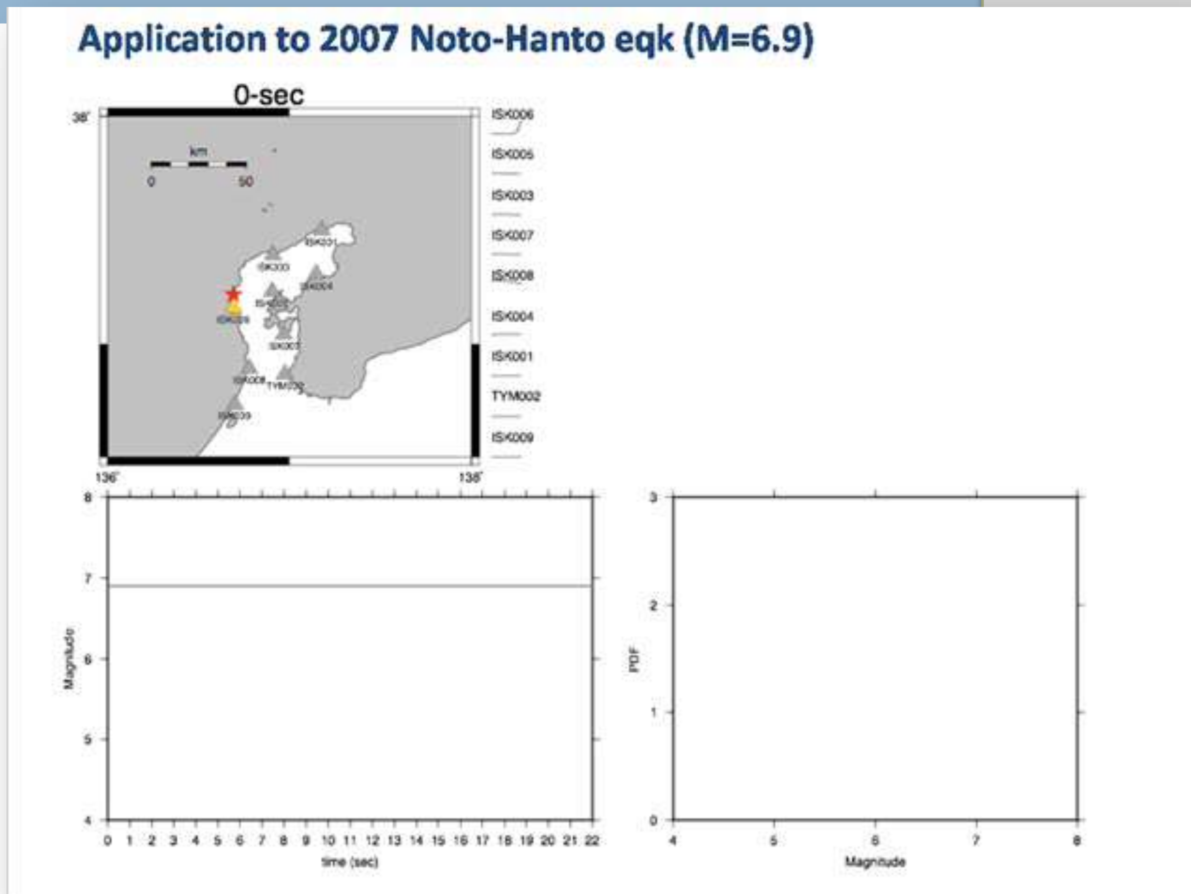
Basic Concepts

- Use of information carried out by early P- and S-waves recorded at a dense, high dynamics network deployed in the source area of earthquakes
- Determine empirical regression laws between real-time measured ground motion parameters (dominant period, peak displacement) and magnitue
- At each time step after first P, evaluate the magnitude using a Bayesian, evolutionary

2007 Noto-Hanto Eqk (M=6.9)

Displacement records

Recording stations

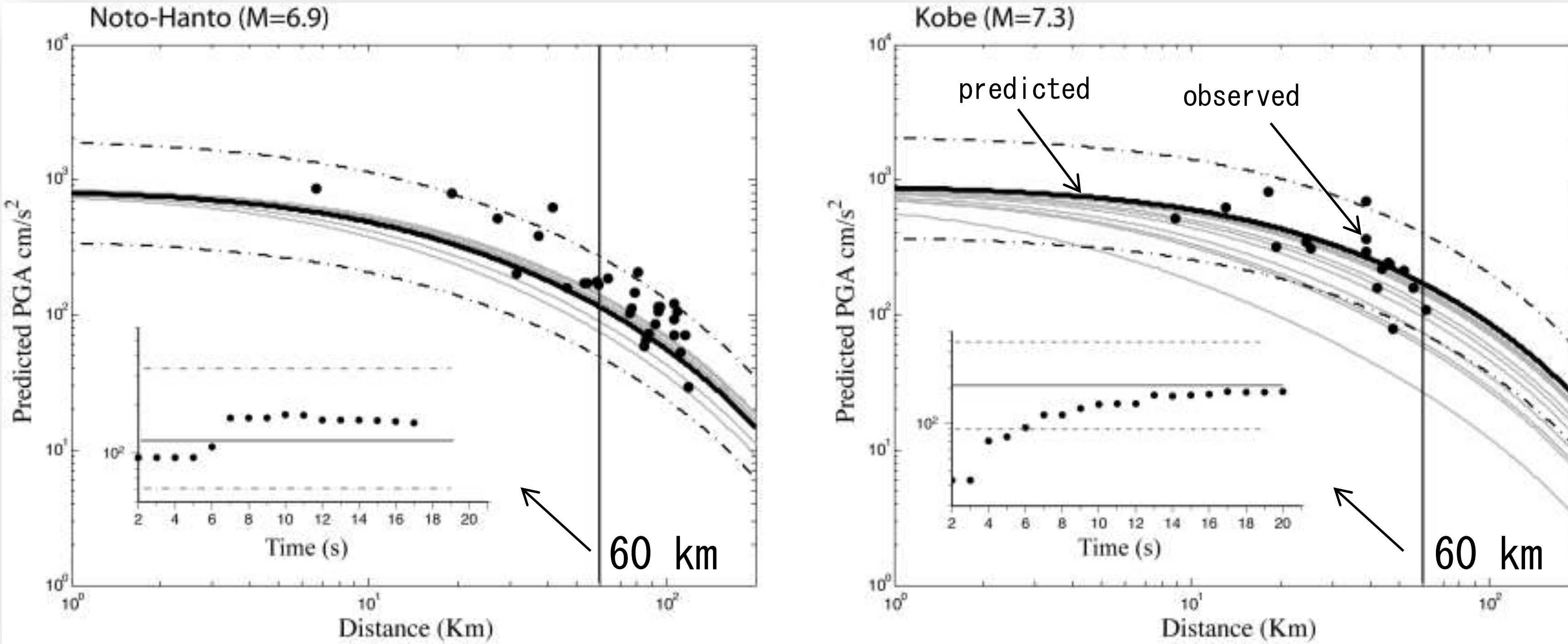


Magnitude Vs Time

Probability density function of Magnitude

Movie

Prediction of Peak Ground motion at the target site



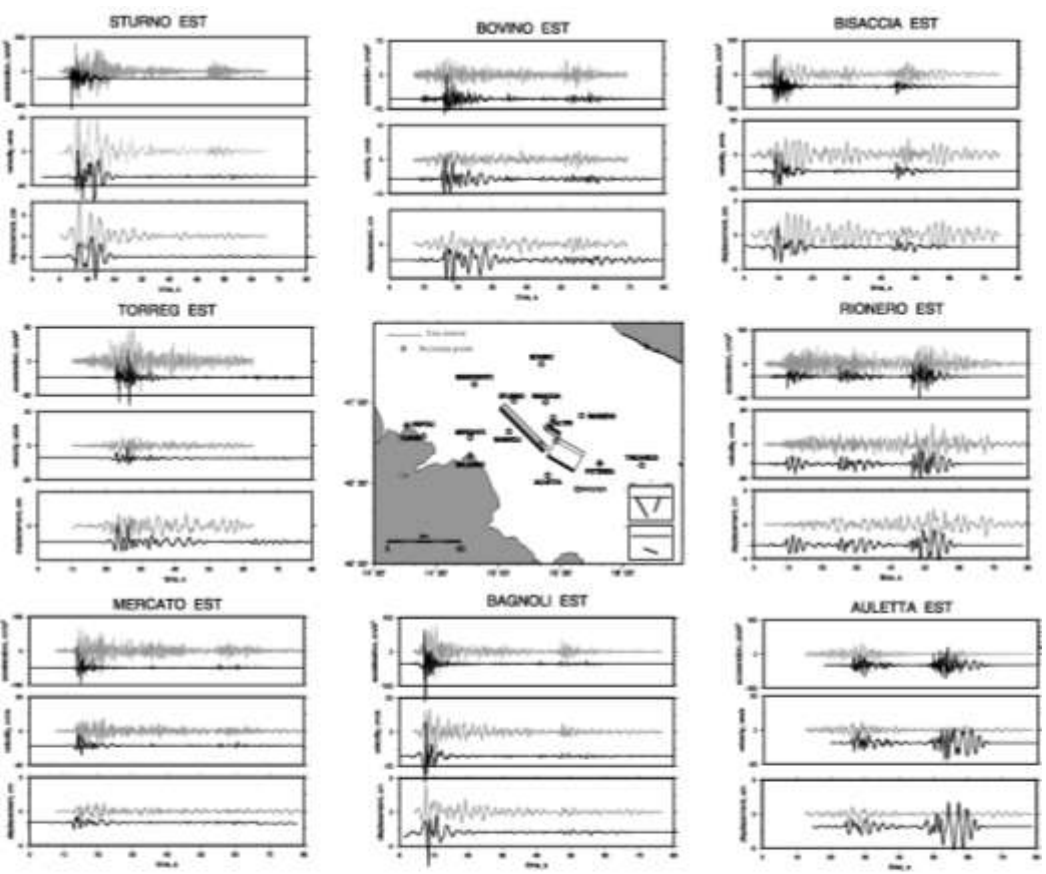
- ❑ Attenuation relationships are used to predict the Peak Ground Acceleration at any time step after first-P detection.
- ❑ Reliable predictions of peak ground motion can be obtained few seconds after the first P arrival at the network, despite of a significant uncertainty in the initial magnitude estimates.

EW System performance

The performance is a measure of the system capability to:

- Rapidly issue a reliable earthquake alert (lead-time)
- Predict the peak motion at a target site with the smallest possible error

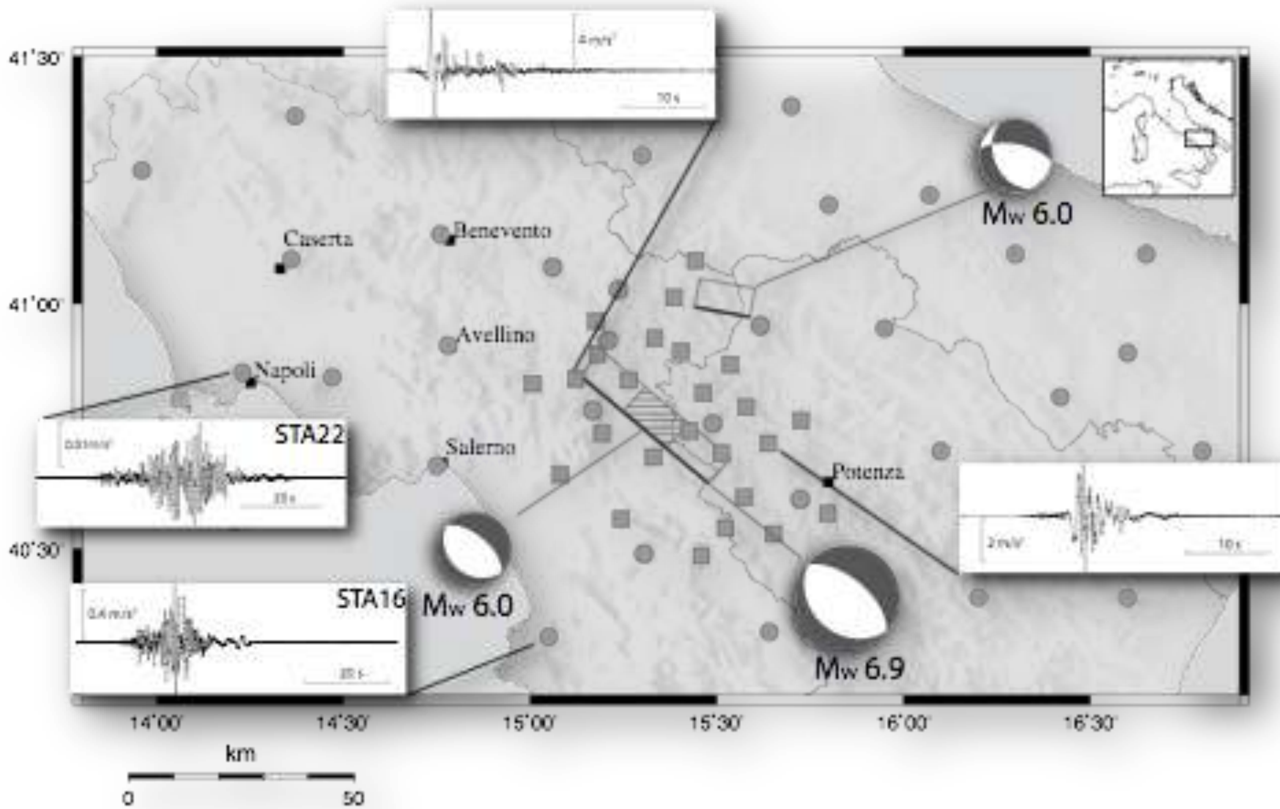
The effect of source size and complexity



- EWS are based on the assumption of a point-like source model and 1-D attenuation model
- For M> 6 and distances <100 km these assumptions may be no more valid
- What are the effects on the performances of an EW system? What parameters can be used to measure the system performance?

A method to evaluate the EW system performance

- Computation of synthetic seismograms for a large number of M6 and M7 earthquake scenarios
- Off-line, but sequentially application of the EW chain of methodologies to investigate the areal distribution of lead-time and prediction error on PGV



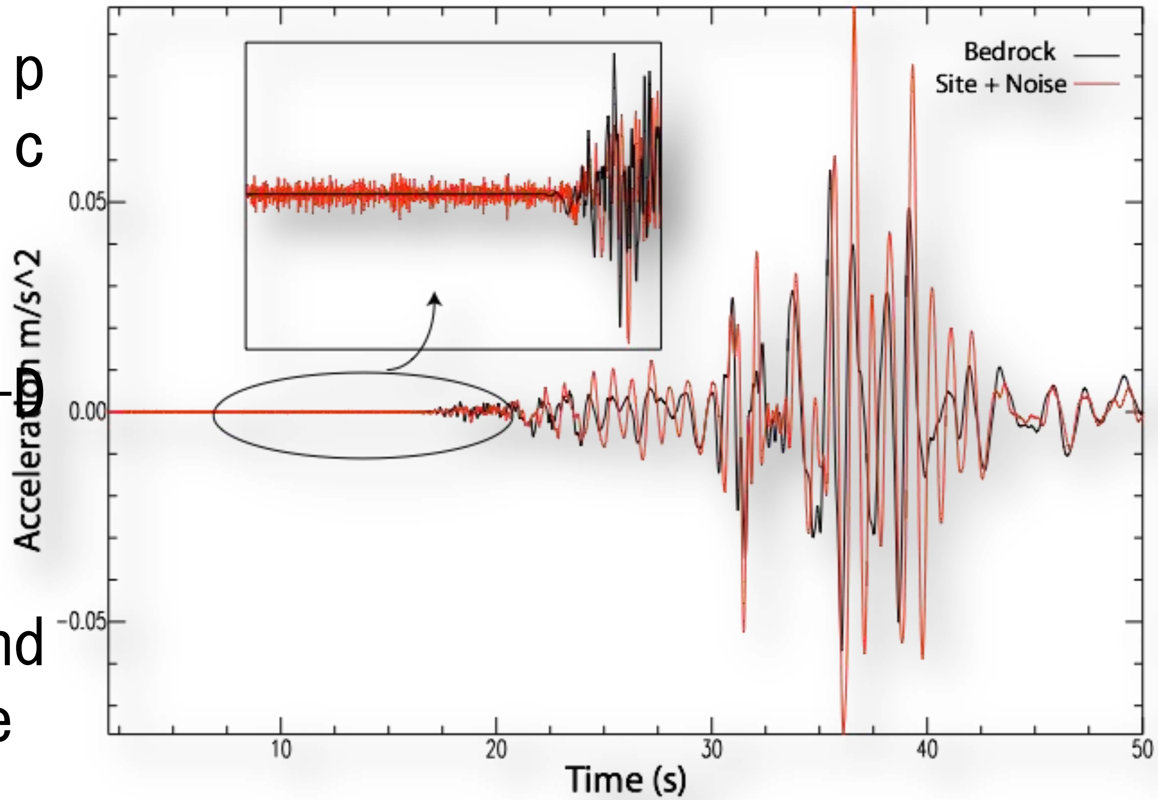
■ Network ISNet

● Network INGV + Virtual

- 300 rupture scenarios for a M 6.9 earthquake
- 90 rupture scenarios for a M 6.0 inside the network
- 90 rupture scenarios for a M 6.0 at the border of the network

Synthetic seismograms

- Hybrid source model based on k-square slip distribution (Gallovic and Brokesova, 2008)
- Complete wavefield Green function in a1-D velocity model
- Waveforms have been noise contaminated and convolved by the site transfer function to account for site effects



Prediction error on PGV

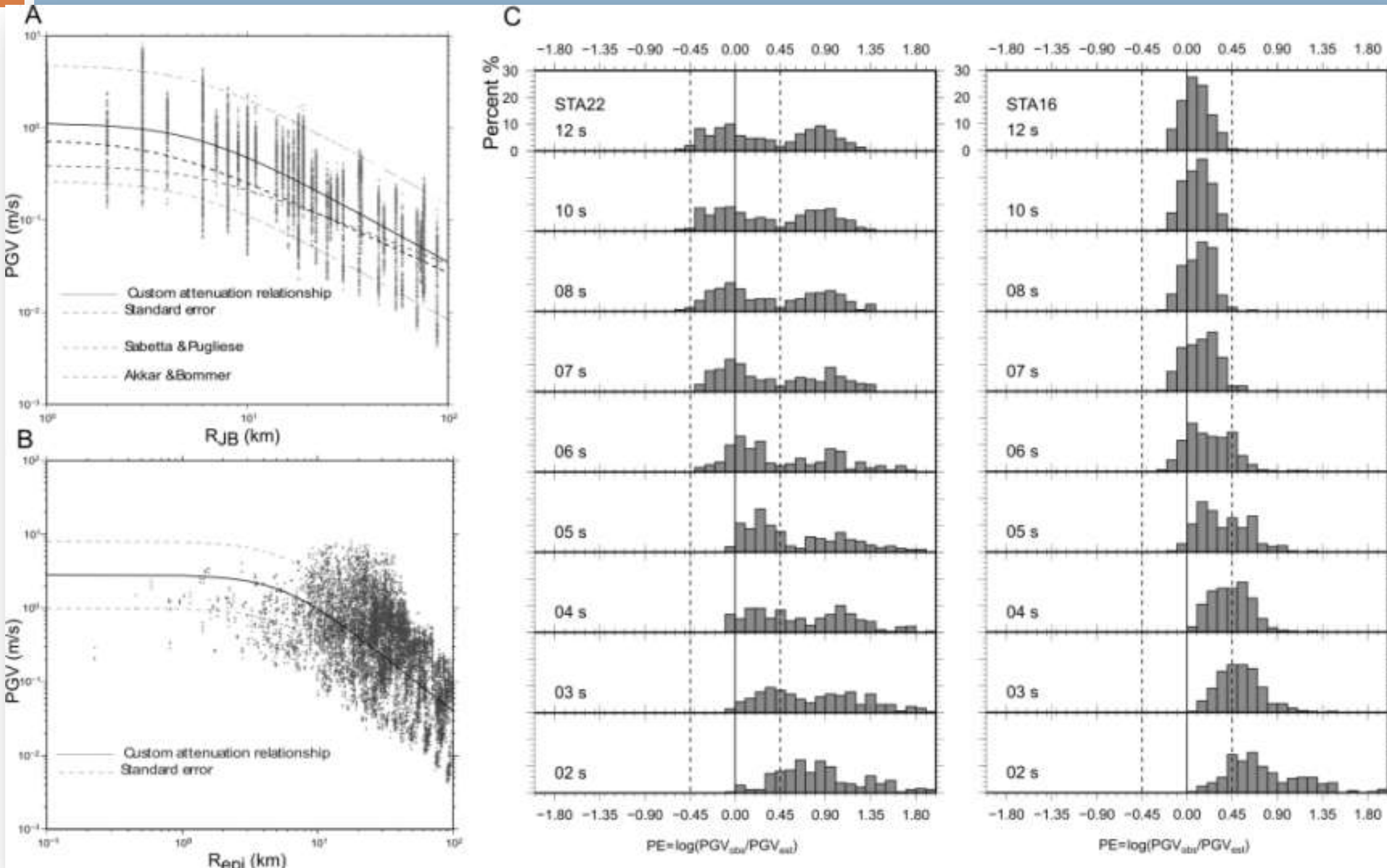
Prediction error definition

$$PE = Log_{10}(PGV_{obs}/PGV_{pred})$$

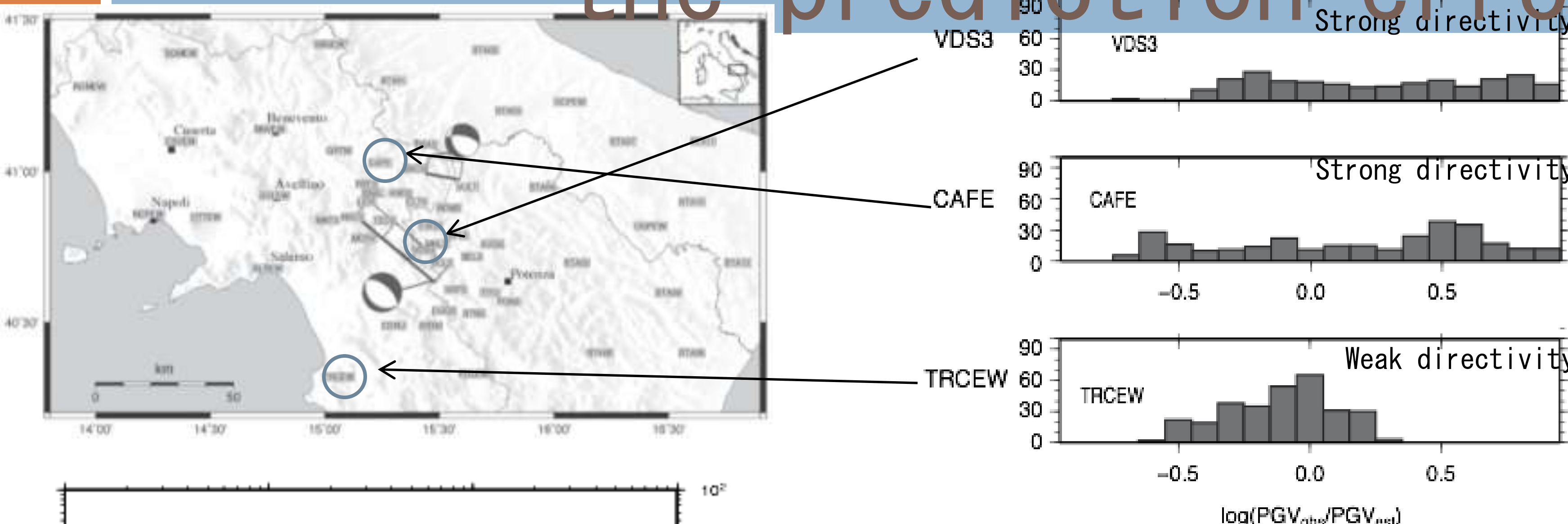
Where PGV_{obs} are measured on synthetics and PGV_{pred} are predicted by the early warning procedure.

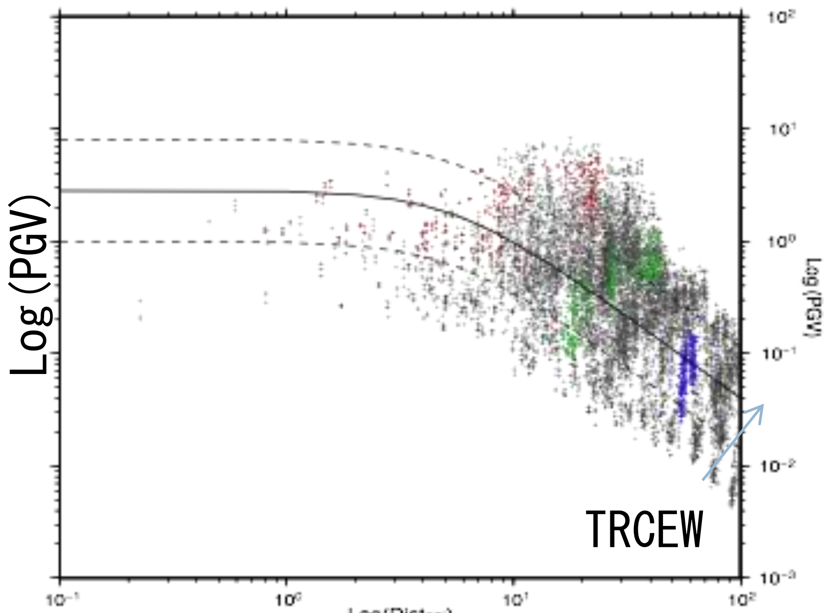
PE is computed as a function of time for the whole number of simulated eqk scenarios.

Empirical attenuation law and prediction error on PGV



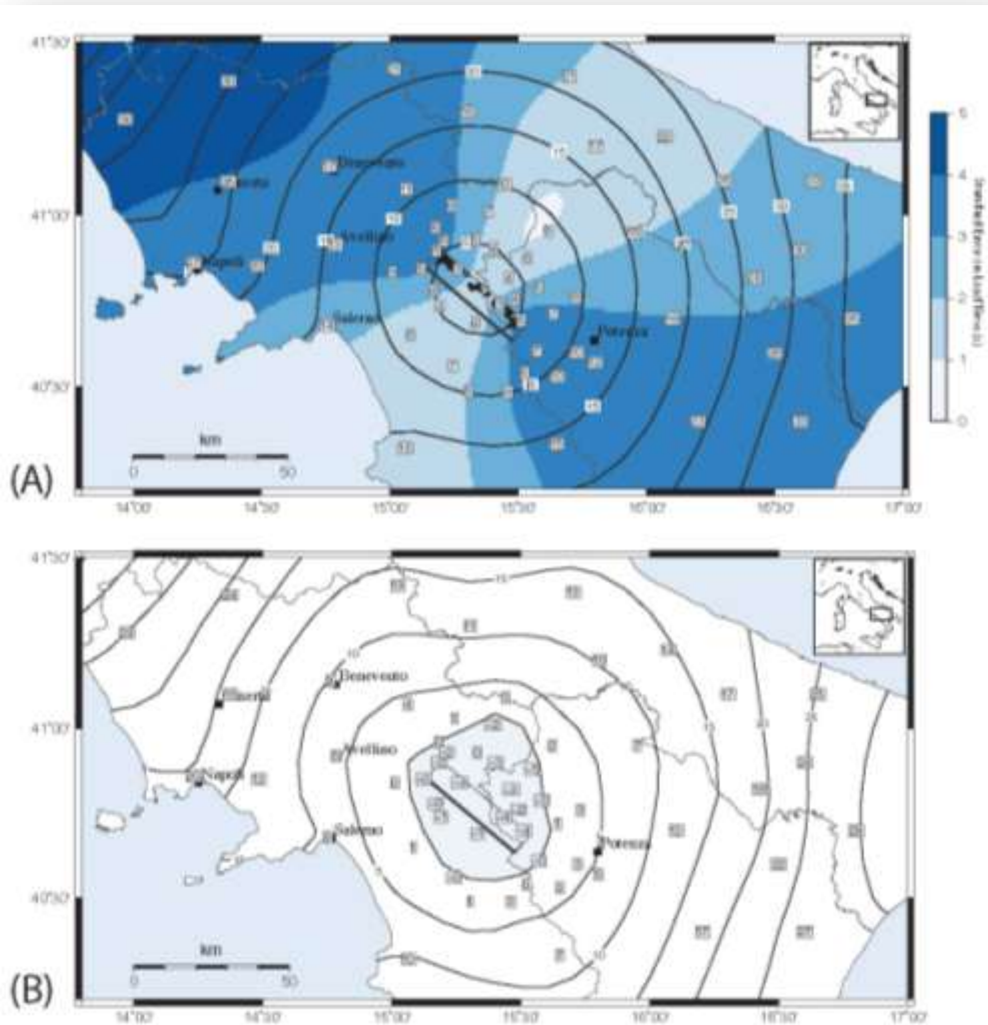
Effects of source complexity on the prediction error





Directivity, radiation pattern and point-source attenuation law determine the azimuthal variation of the prediction error

W System performance (M 7): Lead-Time



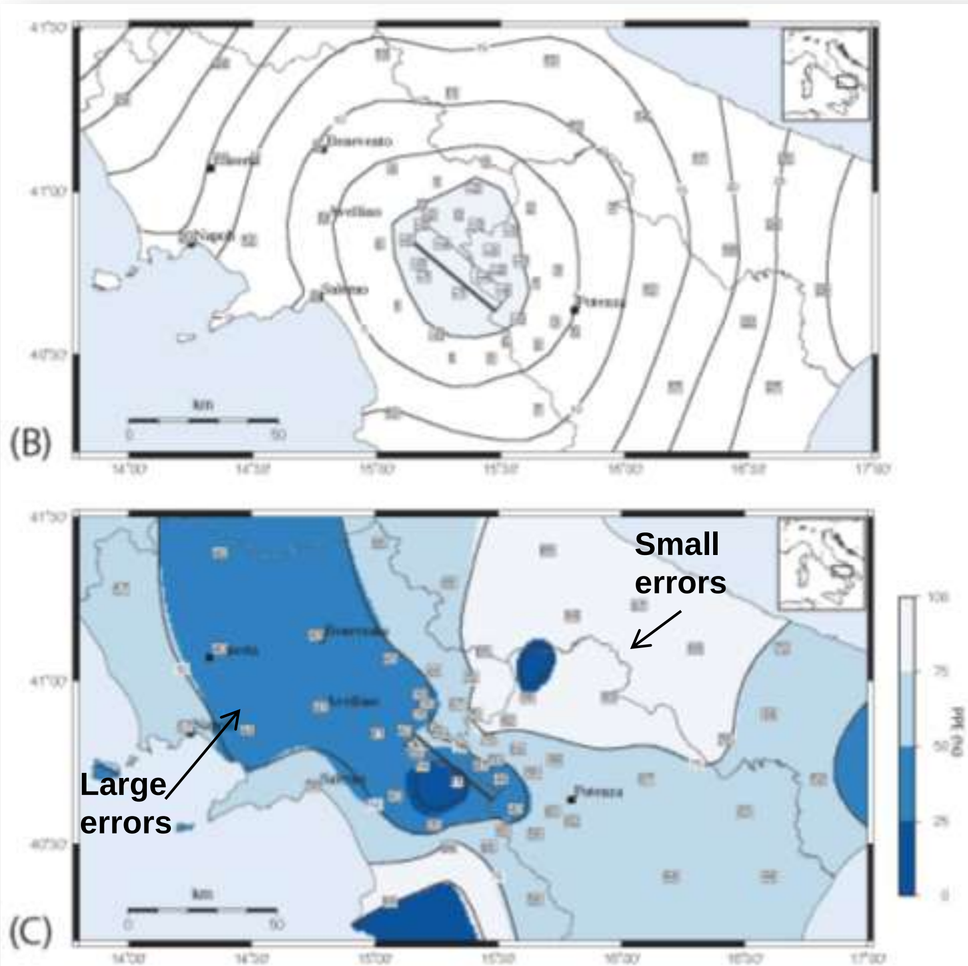
Maximum Lead Time

Time interval between the S-arrival time at the target and the time of first warning (first estimation of magnitude and location)

Effective Lead Time

Time interval between the S-arrival at the target and the time at which the prediction error distribution is stable (no significant variation of magnitude, location after this time)

W System performance (M 7): Prediction error



$$PPE = P(-SE < PE < SE) = \int_{-SE}^{SE} PDF dPE$$

Probability of Prediction Error

The probability that the prediction error ($PE = \log(PGV_{true}) - \log(PGV_{esti})$) is within 1-sigma interval of the standard error on the Ground Motion Prediction Equation. High values of PPE means high performance of the system in terms of prediction of ground shaking level at the target.

Conclusions

- The performance of a “regional” EEW system is influenced by the fault finiteness: smaller lead times, variable prediction error probability (with azimuth, distance)
- Attenuation laws and distance definition: use of empirical scaling relationships to constrain the fault lenght and orientation?
- Maps of effective lead-times and probability of prediction errors can be used to identify the potential applications