

The potential of EEW engineering applications

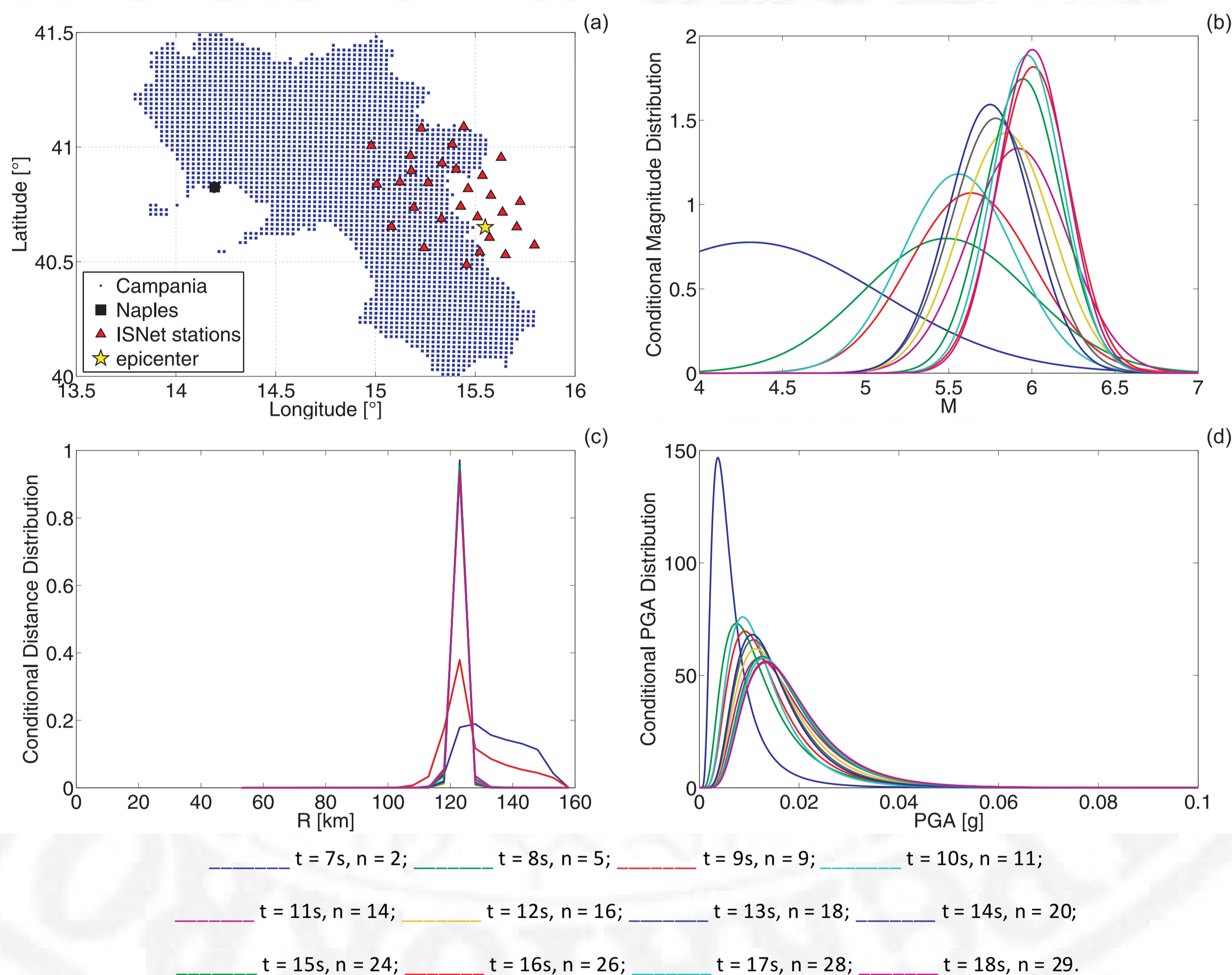
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① Introduction

The development and implementation of an earthquake early warning system (EEWS), both in regional or on-site configurations can help to mitigate the losses due to the occurrence of moderate-to-large earthquakes in densely populated and/or industrialized areas. Some critical issues are peculiar of EEWS and need further investigation: (1) the uncertainties on earthquake magnitude and location estimates based on the measurements of some observed quantities in the very early portion of the recorded signals; (2) the selection of the most appropriate parameter (intensity measure, IM) to be used to predict the ground motion amplitude; (3) the use of the estimates provided by the EEWS for structural engineering and risk mitigation applications. In the present study, the issues above are discussed using the Campania–Lucania region (Southern Apennines) in Italy, as test-site area. In this region a prototype system for earthquake early warning, and more generally for seismic alert management, is under development. The system is based on a dense, wide dynamic accelerometric network (Irpina Seismic Network, ISNet) deployed in the area where the moderate-to-large earthquake causative fault systems are located.



② Real time PSHA and simulation for the Campanian EEWS

The uncertainty analysis is performed by simulation through a real-time Probabilistic Seismic Hazard Analysis (RTPSHA). Recently seismologists developed efficient methods for rapid estimation of event features by means of limited information of the P-waves. Then, when an event is occurring, probabilistic distributions of magnitude and source-to-site distance are available and the prediction of the ground motion at the site, conditioned to the seismic network measures, may be performed in analogy with the classical PSHA (Iervolino et al., 2006, Convertito et al., 2008). Consequently the structural performance may be obtained by the Probabilistic Seismic Demand Analysis (PSDA), and used for real-time risk management purposes (see also Iervolino et al., 2007).

$$f_n(pga | \tau, s) = \int_{M/R} f(pga | m, r) f(m | \tau) f(r | s) dm dr$$

PGA distribution at the site conditioned on the measures of the seismic instruments

Magnitude distribution conditioned on the measures of the seismic instruments

Ordinary attenuation relationship

Distance PDF due to rapid localization method

③ Uncertainty in RTPSHA and lead-time maps

Results of the analyses lead to conclude that: (1) the dominating uncertainty in the real-time hazard analysis is that of the ground motion prediction equation; (2) the estimation of peak ground motion stabilizes only when a certain level of information is reached and, therefore, information-dependent lead-time should be considered for design of engineering applications of EEWS.

The lead-times were computed for the region considering as possible epicenters those randomly occurring in the area which includes the ISNet sensors. Results are given in the form of maps where mean lead-times are computed for each node of a regular grid having about 2 km spacing and covering the territory of the Campania region. The map corresponding to 18 stations was analyzed in respect to a list of real-time risk reduction actions and the time they require.

Figure 1. Results of RTPSHA for Naples in the case of a simulated M 6 event (adapted from Iervolino et al., 2009). (a) Scheme of the network and site. (b) Magnitude distributions. (c) Distance distributions. (d) PGA distributions.

④ The potential of structural control EEW applications

Possible interaction between EEWS and Structural Control is a quite recent subject still to be fully investigated. Feasible implementations of structural control rely substantially on semi-active (SA) devices. Technological and reliability-based issues prevent in most cases the adoption of fully active control systems.

The principal characteristic of SA systems is that control forces are not realized, as in the active case, by using externally positioned actuators (which in civil applications require large power supply), but by modifying, in real-time and according to a preselected decisional rule, the mechanical characteristics of special devices (SA links), that interact (through internal 'reactive' control forces) with the structure. The energy required for the modification of the mechanical parameters of the devices is minimal, and may be furnished even by a simple battery.

One means of achieving a semi-active damping device is to use a controllable, electromechanical, variable-orifice valve to alter the resistance to flow of a conventional (passive) hydraulic fluid damper.

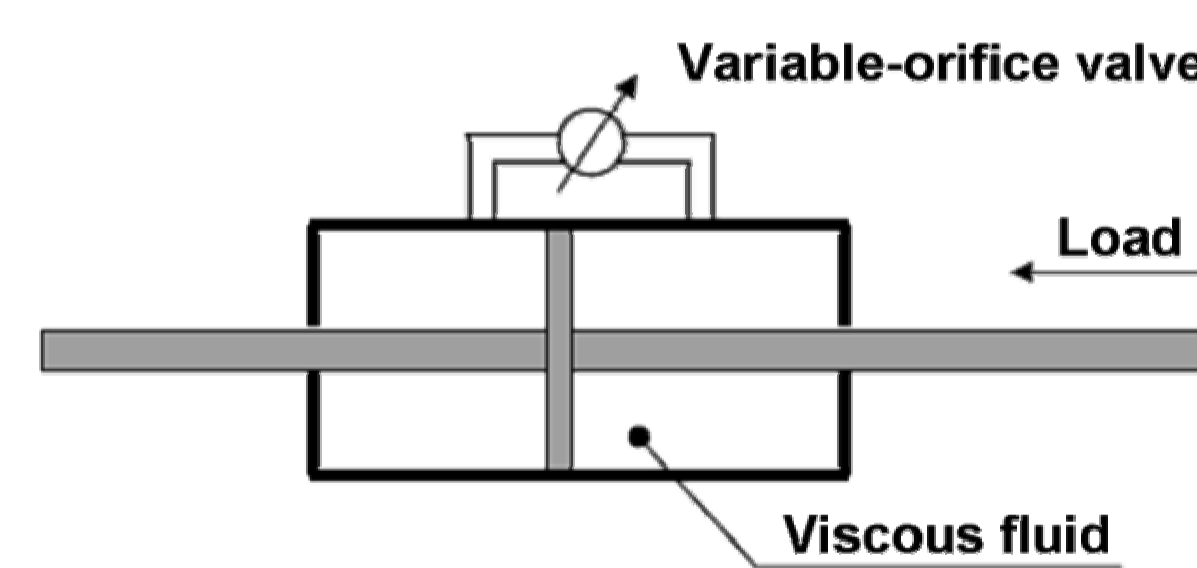


Figure 3. Variable fluid viscous damper

The reference structure is modelled as a T = 0.6s single degree of freedom (SDOF) with an elastic-perfectly-plastic behavior and a yielding moment of 200kNm.

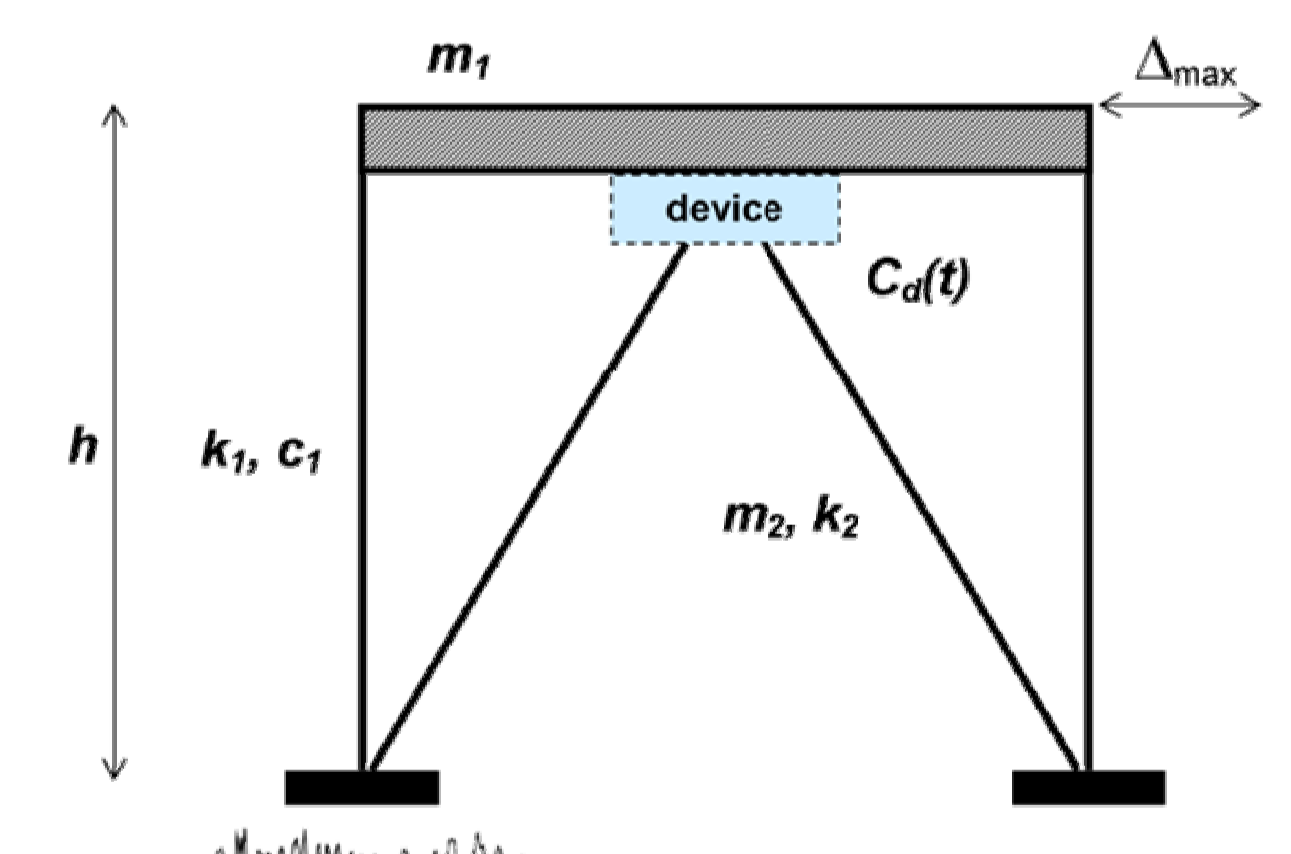


Figure 4. Reference structure

The structure is equipped with a bracing system including variable viscous dampers operating in semi-active (SA) ON-OFF mode and working with the EEWS that determines the activation of the device.

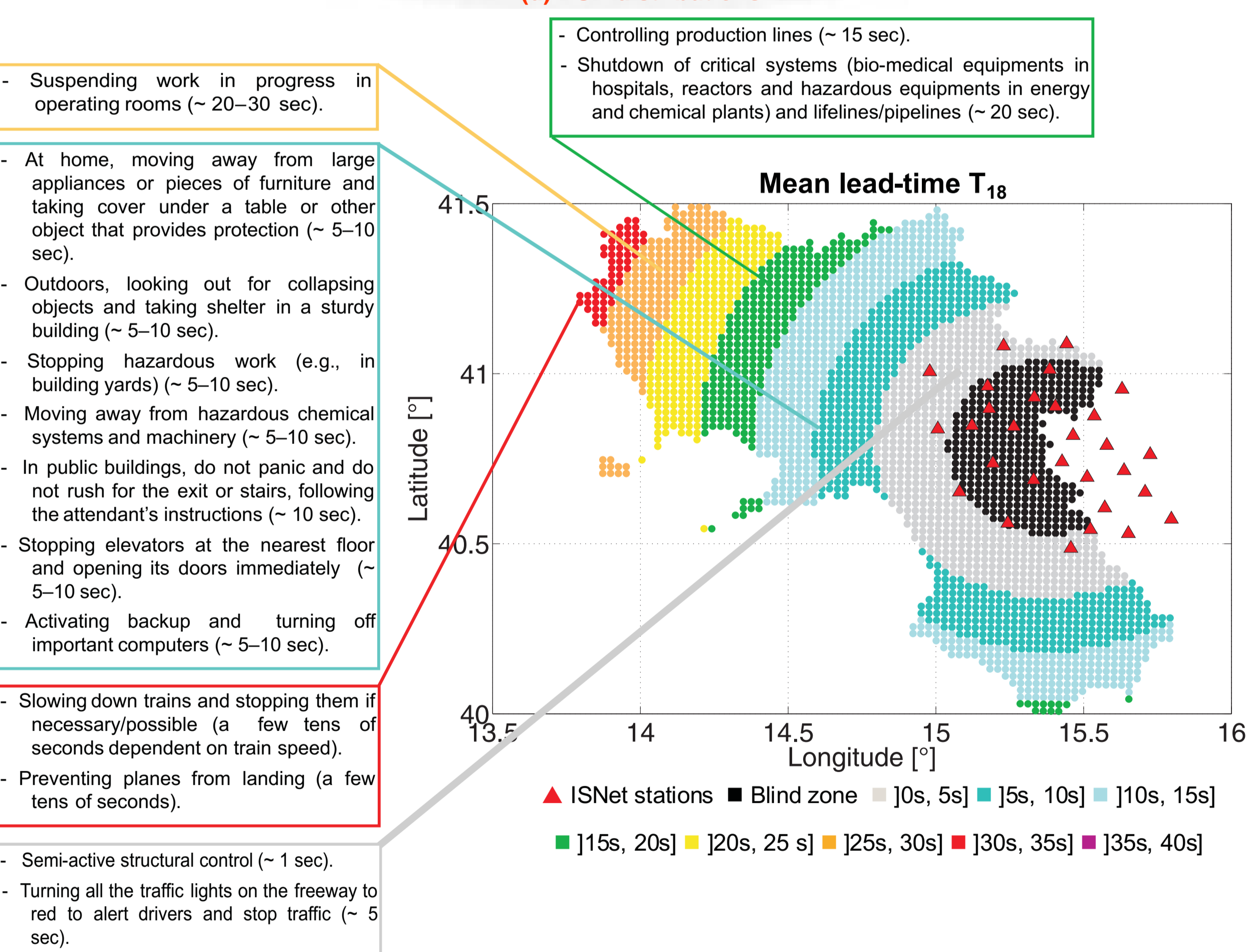


Figure 2. 18-stations lead-time map for the Campania region in the case of an event within area covered by the ISNet network and possible risk reduction actions (adapted from Iervolino et al., 2009).

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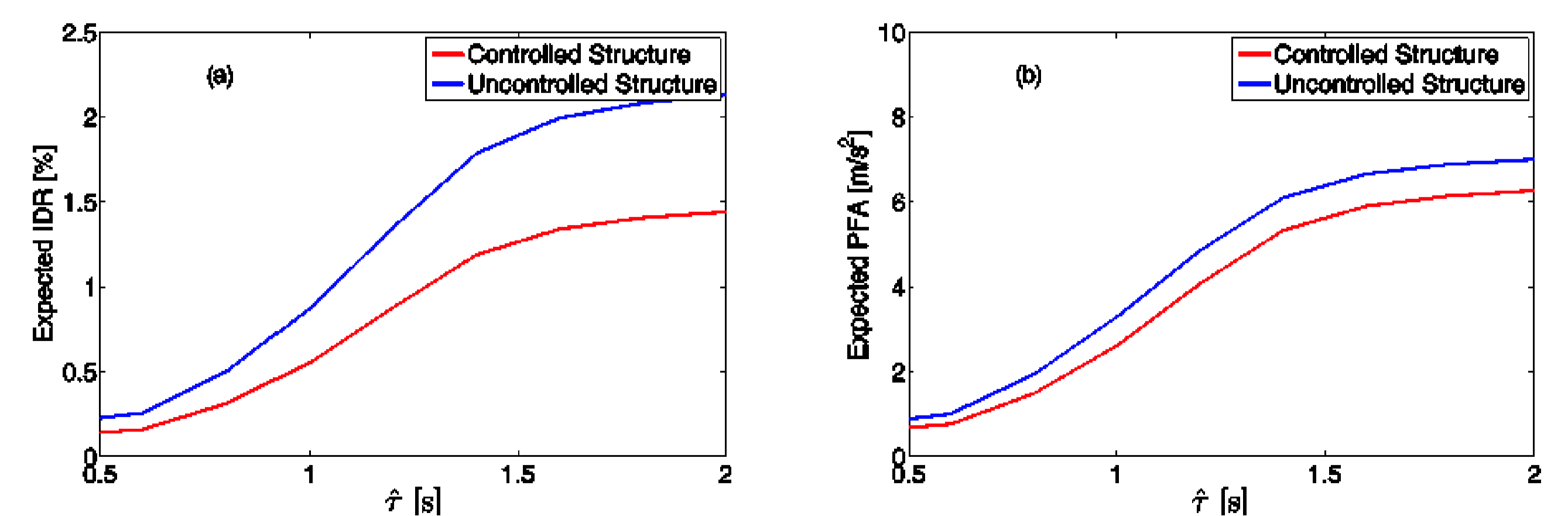


Figure 5. Comparison between the expected IDR (a) and PFA (b) of controlled and uncontrolled structure as a function of the statistics of the network measurements.