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Scenario-based Earthquake Early Warning Empowered by NDSHA (EGU22-13334)

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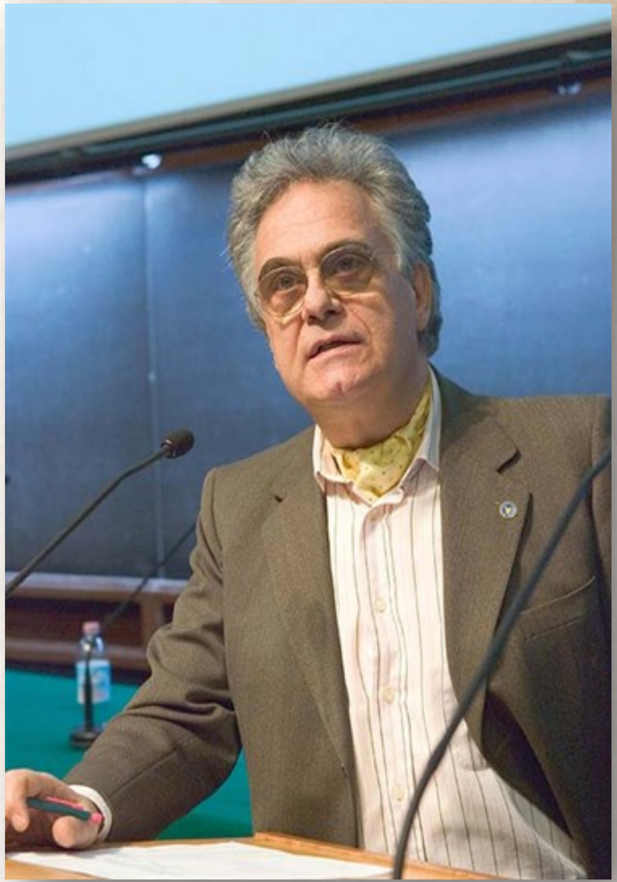
Giuliano Panza

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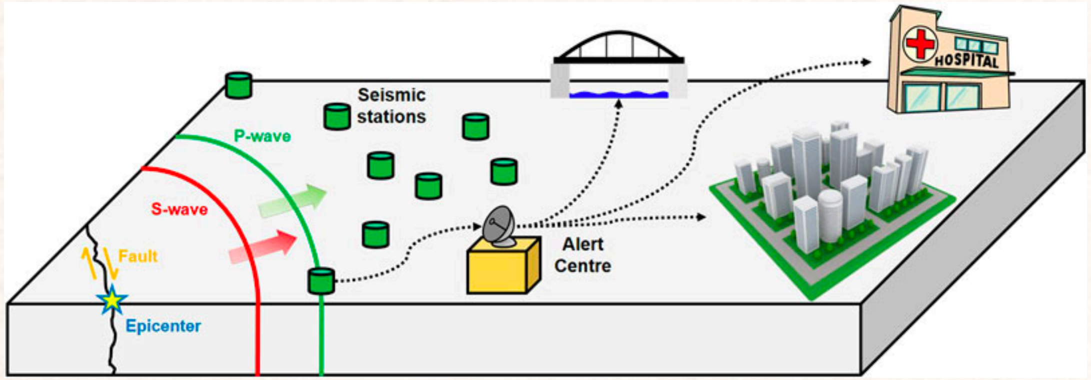

Velazquez et al., 2020

Case 1: China high speed railway

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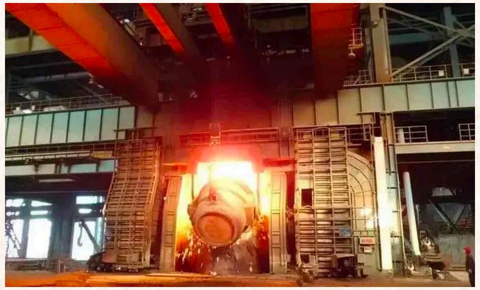

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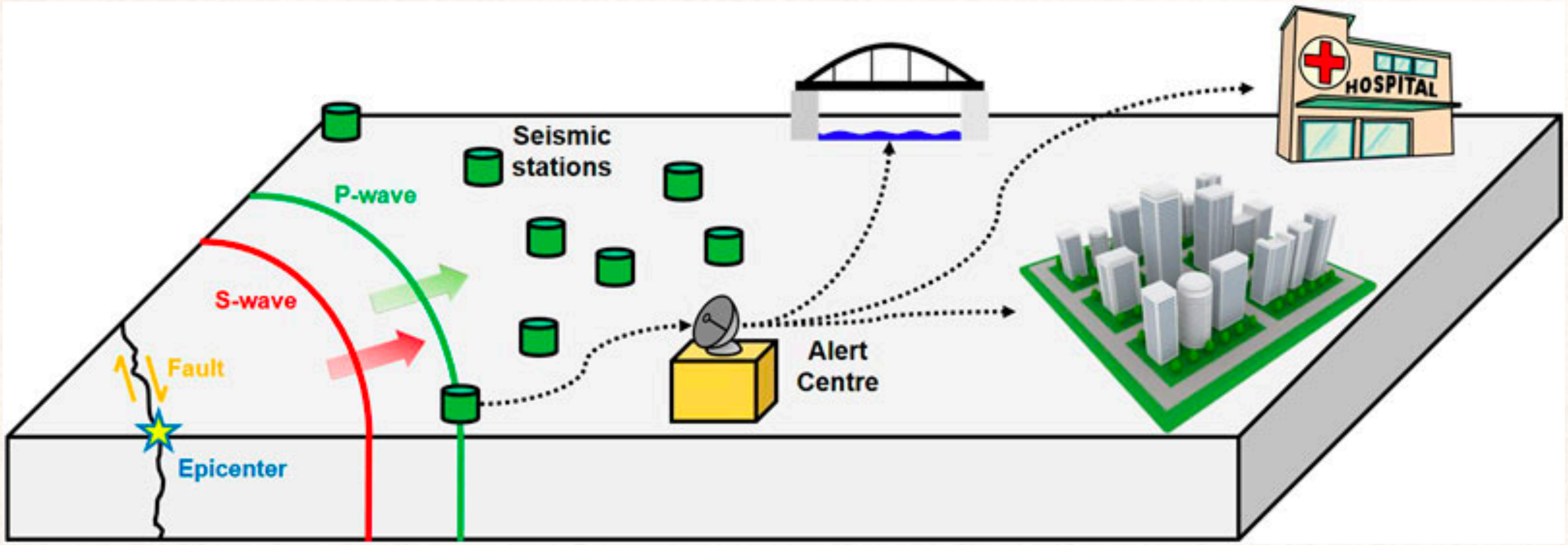
Earthquake Early Warning

* Detecting earthquakes
* Issuing warnings
* Emergency preparedness
* Protecting lives and economies

1 / Earthquake Early Warning

Elements and functions

Front-detection EEW, for far earthquakes away from the cities



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From PSHA-based to NDSHA-based

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Earthquake early warning: Recent advances and perspectives

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A R T I C L E I N F O

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Engineering-related risk prediction
Decision-making under uncertainty
Resilience promotion

A B S T R A C T

Earthquake early warning (EEW) is a relatively new strategy for reducing disaster risk and increasing resilience to seismic hazard in urban settings. EEW systems provide real-time information about ongoing earthquakes, enabling individuals, communities, governments, businesses and others located at distance to take timely action to reduce the probability of harm or loss before the earthquake-induced ground shaking reaches them. Examples of potential losses mitigated by EEW systems include injuries and infrastructure downtime. These systems are currently operating in nine countries, and are being/have been tested for implementation in 13 more. This paper reviews state-of-the-art approaches to EEW around the world. We specifically focus on the various algorithms that have been developed for the rapid calculation of seismic-source parameters, ground shaking, and potential consequences in the wake of an event. We also discuss limitations of the existing applied methodologies, with a particular emphasis on the lack of engineering-related (i.e., risk and resilience) metrics currently used to support decision-making related to the triggering of alerts by various end users. Finally, we provide a number of suggestions for future end-user-orientated advances in the field of EEW. For example, we propose that next-generation EEW systems should incorporate engineering-based, application-specific models/tools for more effective risk communication. They should operate within robust probabilistic frameworks that explicitly quantify uncertainties at each stage of the analysis, for more informed stakeholder decision-making. These types of advancements in EEW systems would represent an important paradigm shift in current approaches to issuing early warnings for natural hazards.

1. Introduction

Early warning consists of a set of procedures and tools for disseminating actionable information in advance of a threatening circumstance, to reduce the potential risks involved (Basher et al., 2006). Early warning systems are increasingly considered an important and effective way to mitigate the effects of natural hazards (United Nations, 2006). It is therefore not surprising that they are frequently used to send alerts related to floods (e.g., Krzysztofowicz et al., 1994), tornados (e.g., Simmons and Sutter, 2009), avalanches (e.g., Rheinberger, 2013), glacier lake outbursts (e.g., Bründl and Sturny, 2014), landslides (e.g., Medina-Cetina and Nadim, 2008), debris flows (e.g., Sättele et al., 2015), and tsunamis (e.g., Blaser et al., 2011). In this paper, we focus specifically on their application to earthquakes.

Earthquake early warning (EEW) systems are primarily based on two concepts that enable alerts to be sent ahead of the occurrence of earthquake-induced ground shaking at target locations (on the order of seconds to minutes): (1) Information travels faster than seismic (i.e., mechanical) waves; and (2) most of the energy of an earthquake is carried by the S- and surface waves, which arrive after the faster, lower amplitude P-waves. This warning time, although short, can reduce the impacts of an earthquake on many sectors of society (Strauss and Allen, 2016). Individuals can "drop, cover and hold on" or (if there is sufficient time) evacuate hazardous buildings/move to safer locations within a building, mitigating injuries or fatalities. Automated actions can be taken, including the stopping of elevators at the nearest floor and opening the doors to avoid injuries, the slowing of high-speed trains to reduce accidents, the shutting down of gas pipelines to prevent fires, and the switching of signals to stop vehicles from entering vulnerable structures such as bridges and tunnels, etc. This is not an exhaustive list but rather a snapshot of critical applications that could benefit from EEW.

The idea of using early warning for earthquakes was first considered by J.D. Cooper in November 1868 (Nakamura and Tucker, 1988); he proposed the installation of seismic sensors near Hollister, California, that would send an electric signal via telegraph to San Francisco once an earthquake was detected. EEW was not practically implemented until the 1960's however, when the Japanese National Railways authority developed an EEW system to avoid derailments of high-speed trains (Nakamura and Saita, 2007). The concept was further enhanced

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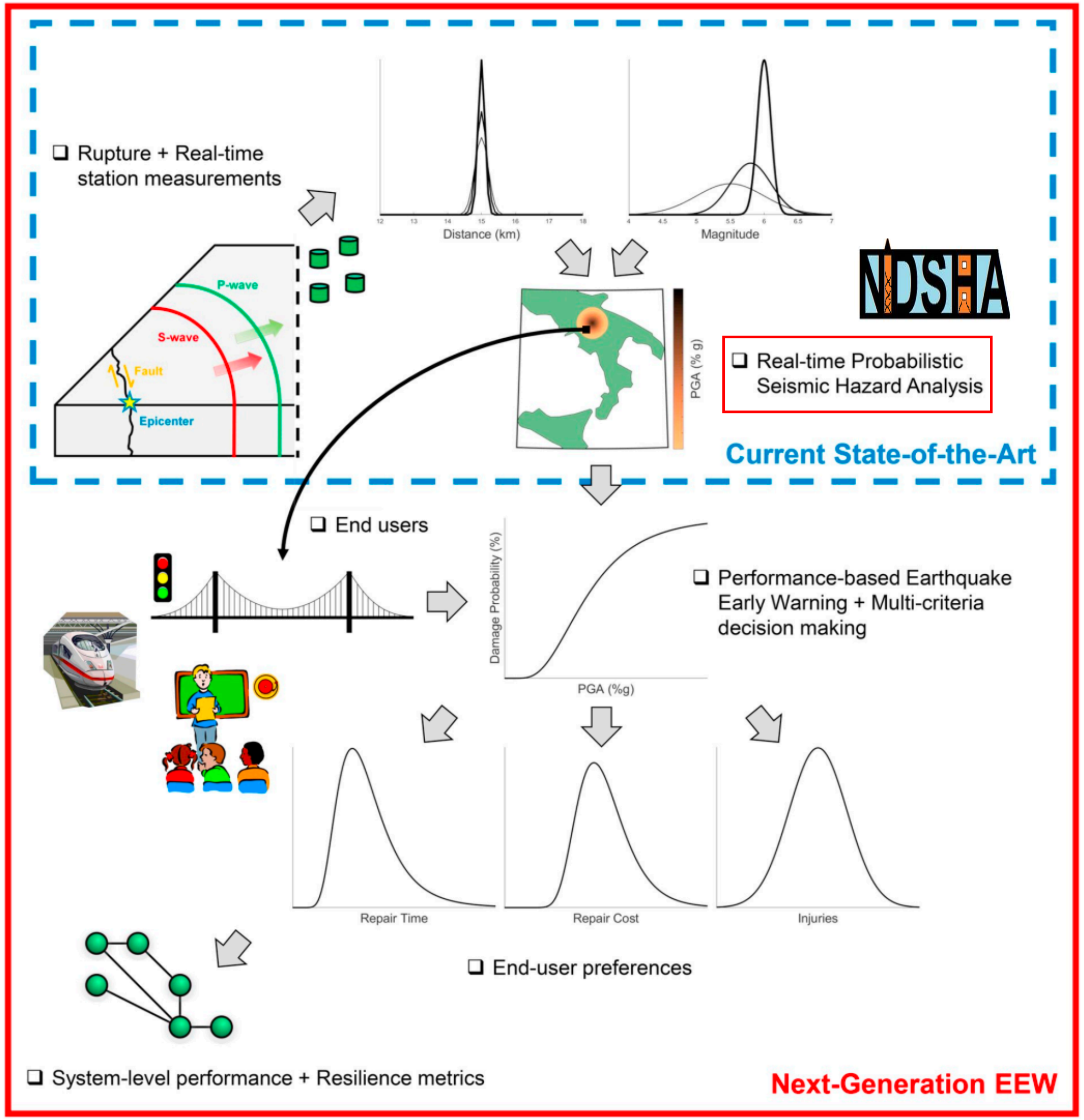
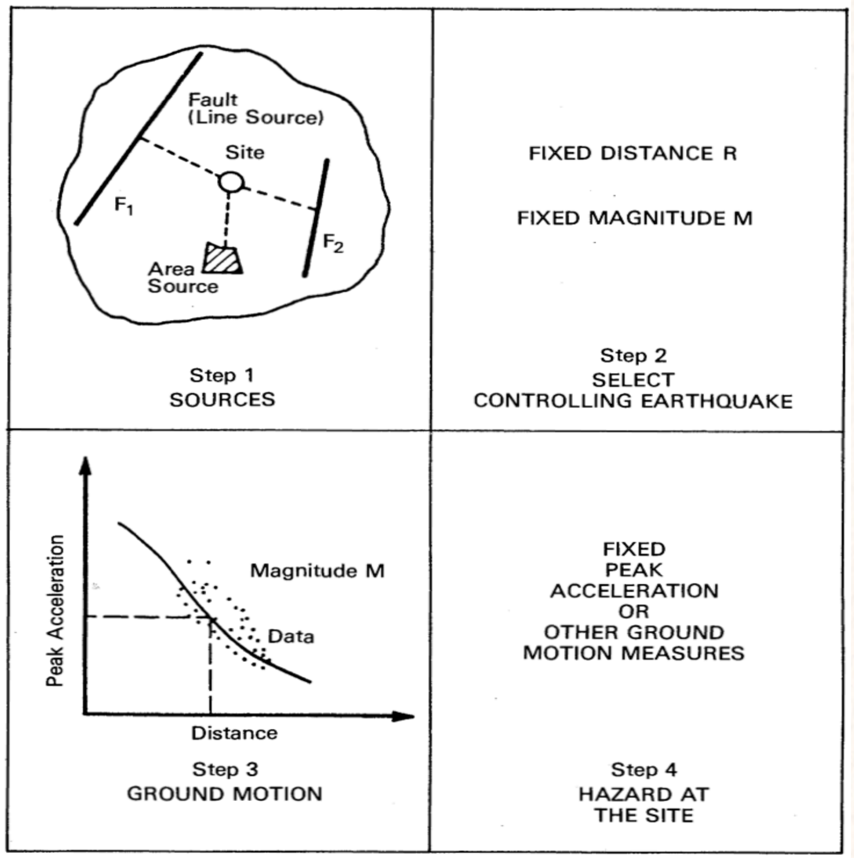


(Cremen and Galasso, 2020)

2 / The next-generation EEW?

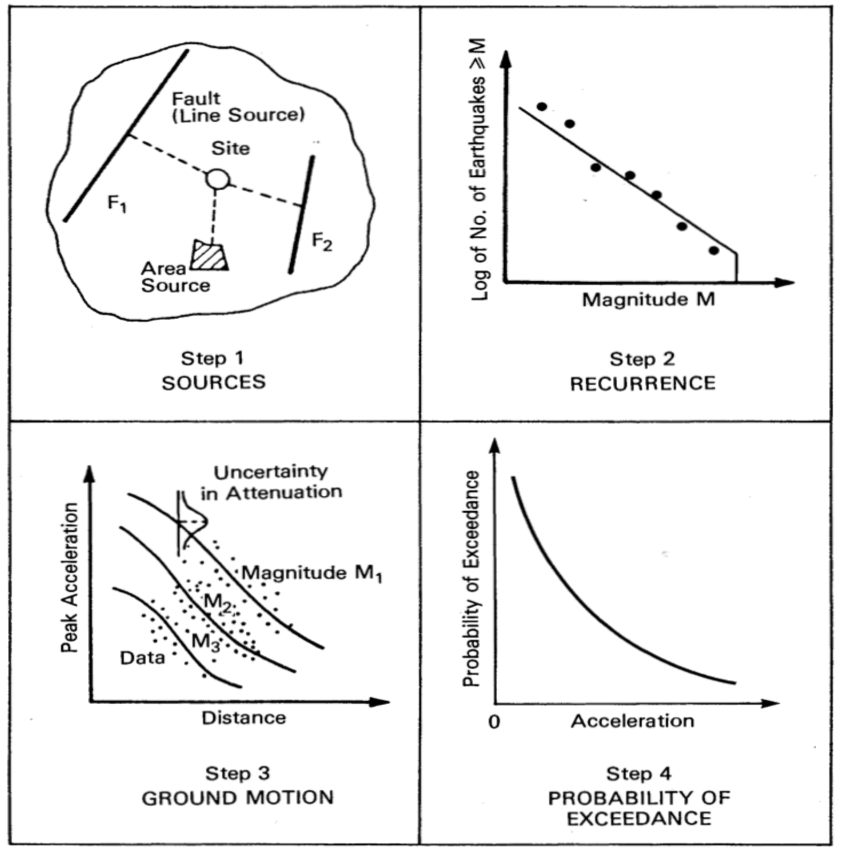
From PSHA-based to NDSHA-based

Reiter, 1990



Deterministic Seismic Hazard Assessment (DSHA)

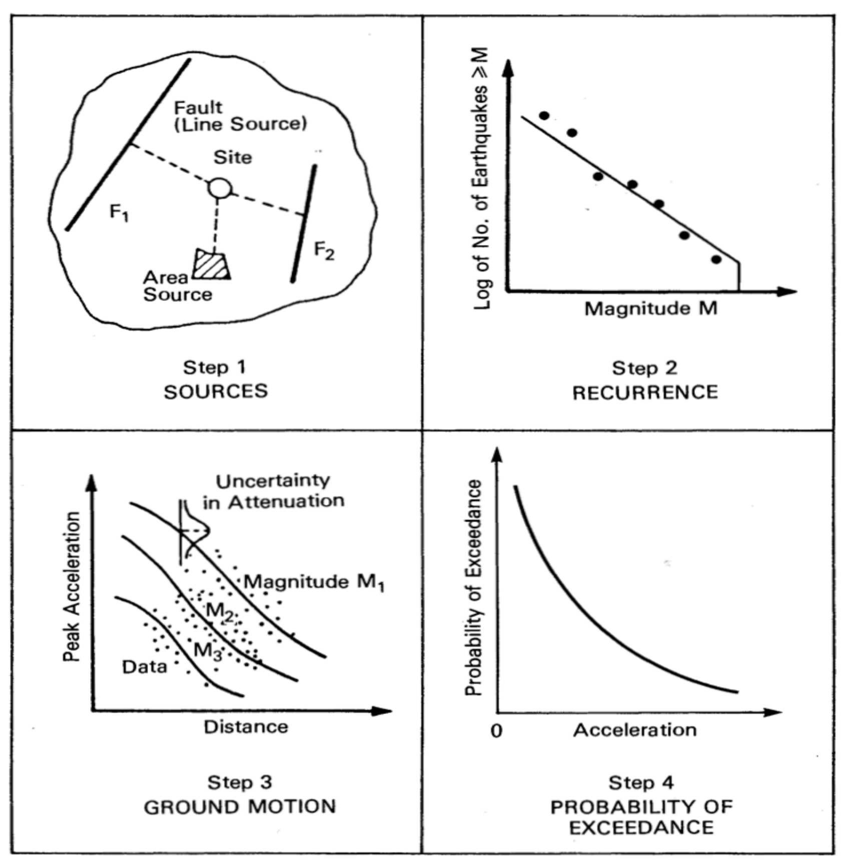
Reiter, 1990



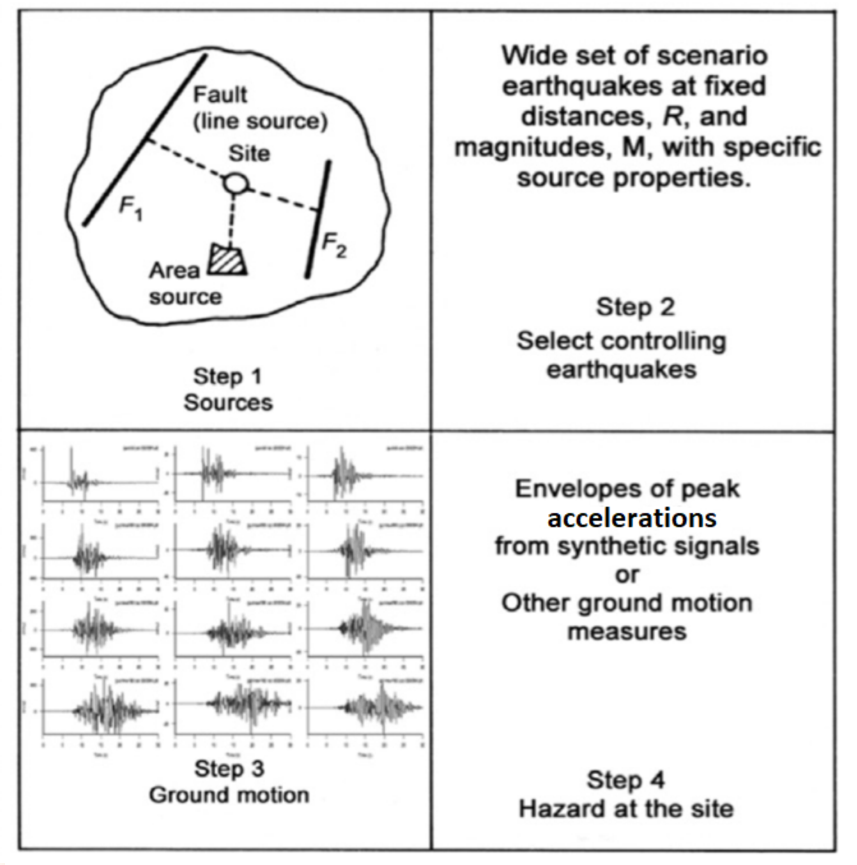
Probabilistic Seismic Hazard Assessment (PSHA)

2 / The next-generation EEW?

From PSHA-based to NDSHA-based



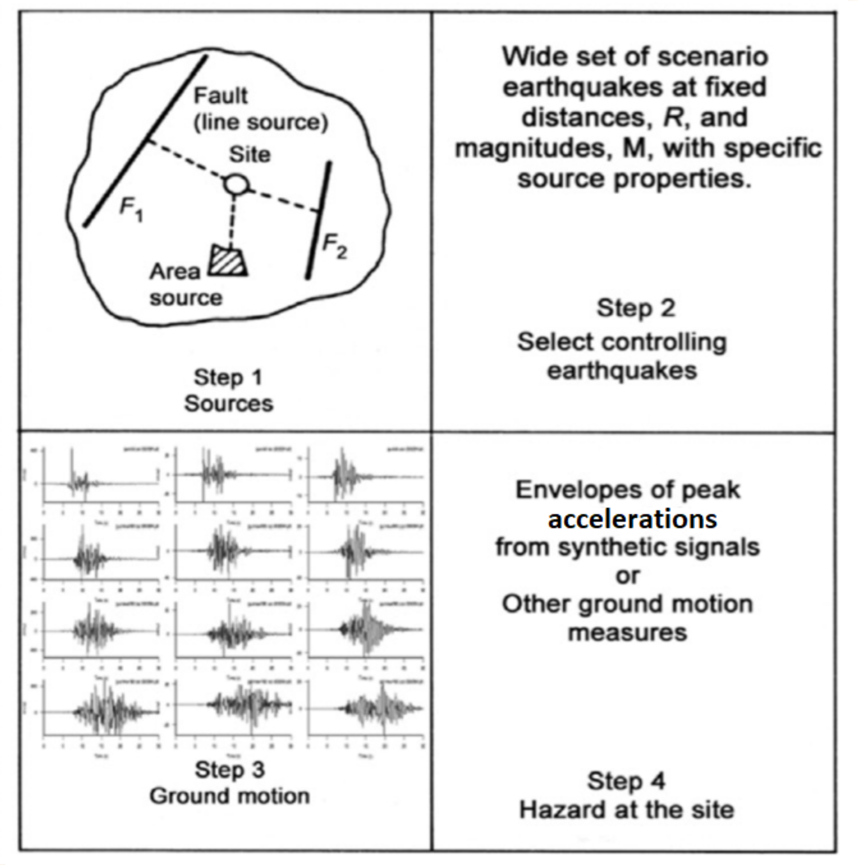
Probabilistic Seismic Hazard Assessment (PSHA)



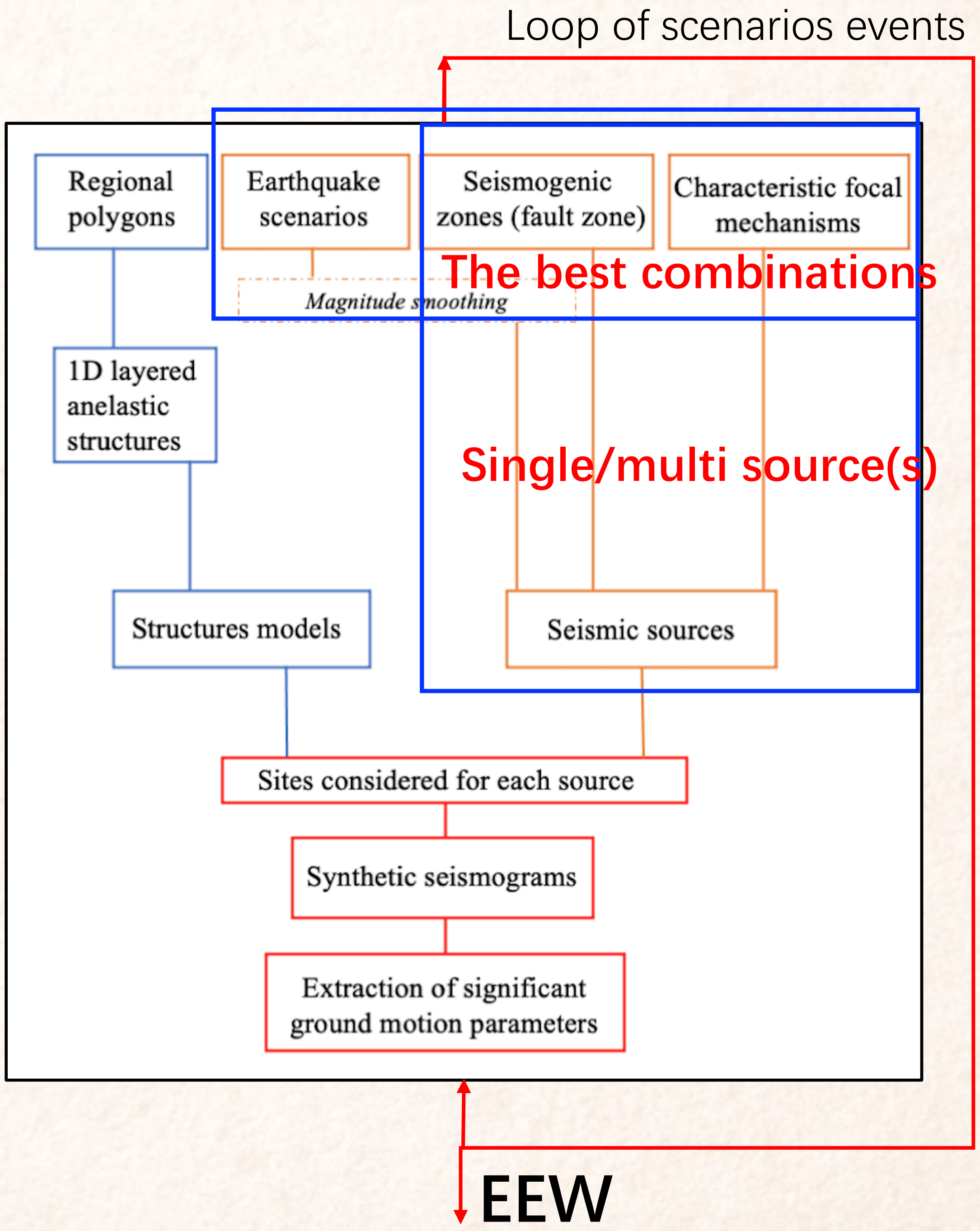
Neo-deterministic Seismic Hazard Assessment (NDSHA)

2 / The next-generation EEW?

From PSHA-based to NDSHA-based

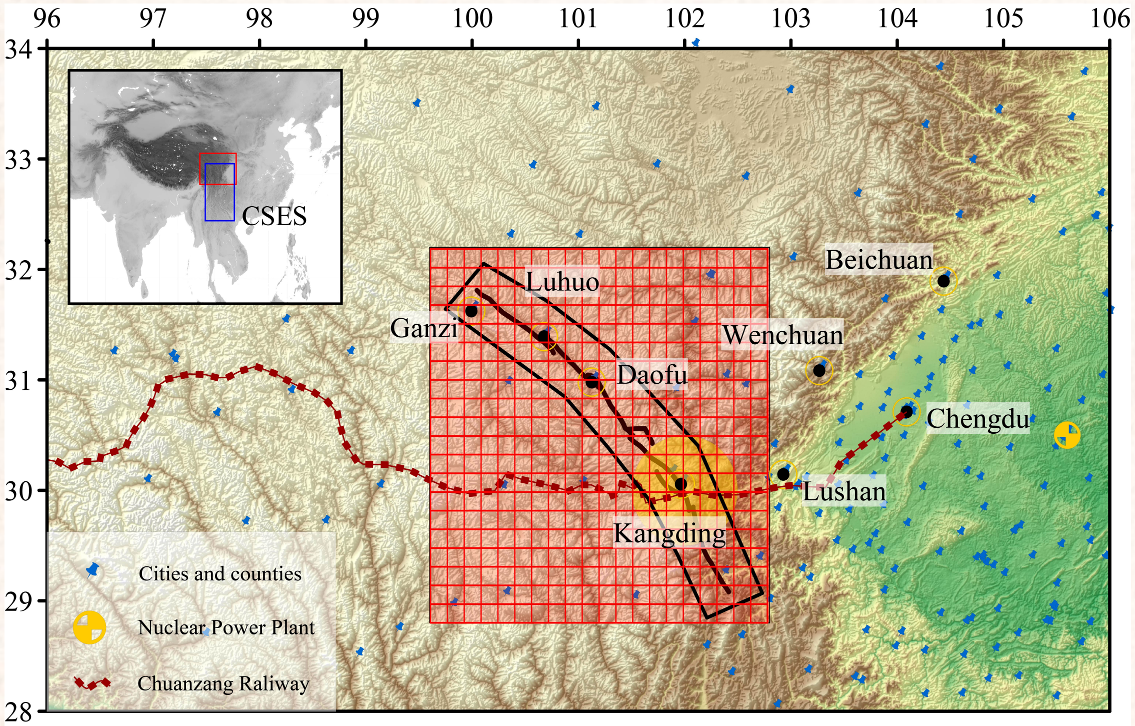


Neo-deterministic Seismic Hazard Assessment (NDSHA)

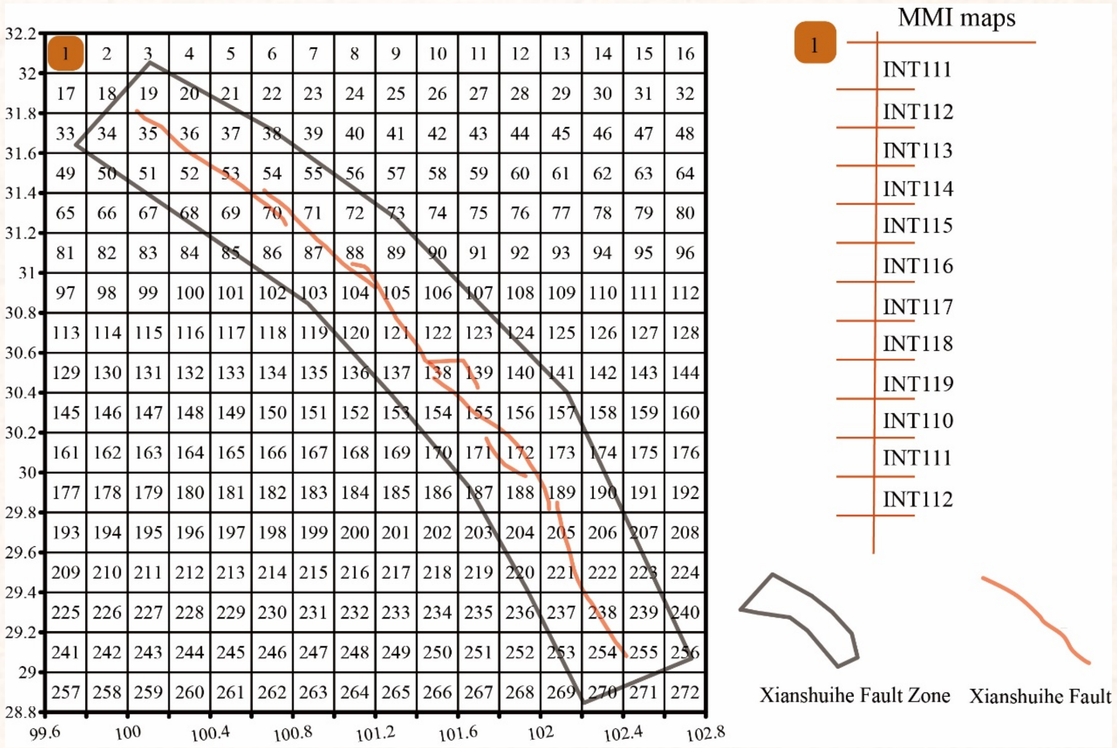


3 / EEWS empowered by NDSHA

Methodology and implementation



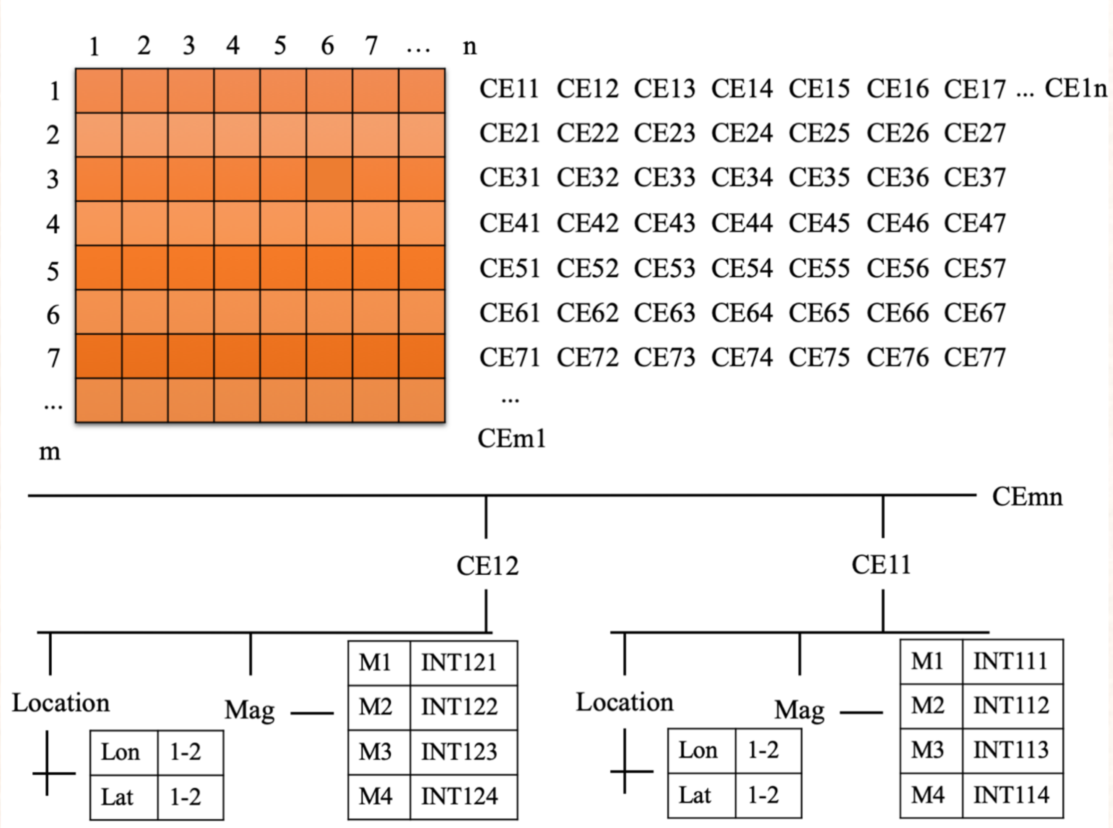
North to China Seismic Experimental Site (CSES),
The Xianshuihe fault (XSH)

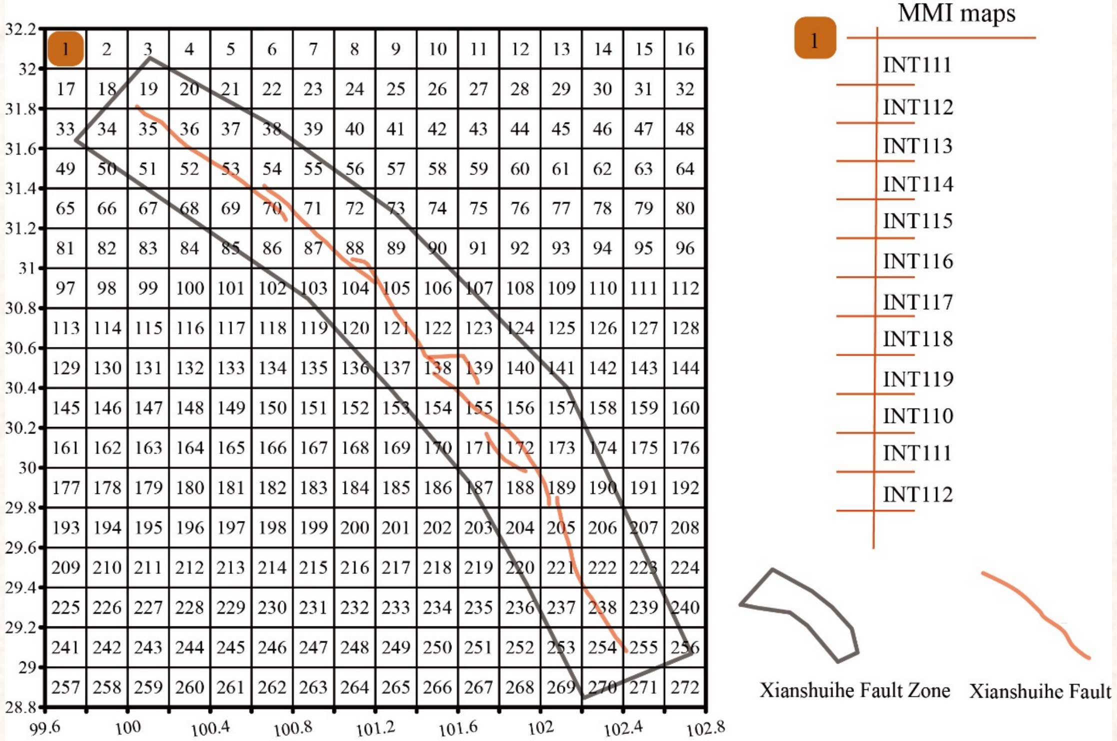


0.2°x0.2° Source Gridding

3 / EEWS empowered by NDSHA

Methodology and implementation





Database of MMI

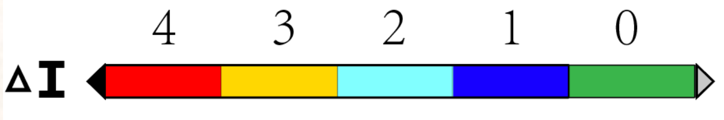
3 / EEWS empowered by NDSHA

Methodology and implementation

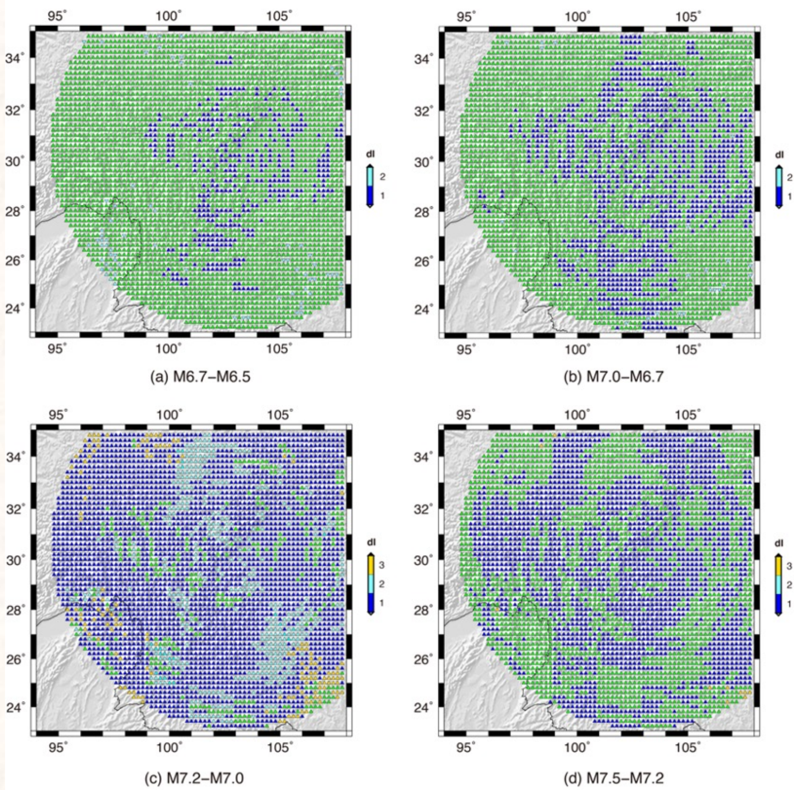
Classification of magnitude

Class	I: $5.0 \leq M < 7.0$	II: $7.0 \leq M < 8.0$	III: $M \geq 8.0$
A	$5.0 \leq M < 5.5$	$7.0 \leq M < 7.2$	$8.0 \leq M < 8.2$
B	$5.5 \leq M < 6.0$	$7.2 \leq M < 7.4$	$8.2 \leq M < 8.4$
C	$6.0 \leq M < 6.5$	$7.4 \leq M < 7.6$	$8.4 \leq M < 8.6$
D	$6.5 \leq M < 7.0$	$7.6 \leq M < 7.8$	
E		$7.8 \leq M < 8.0$	

$\triangle I < 2$

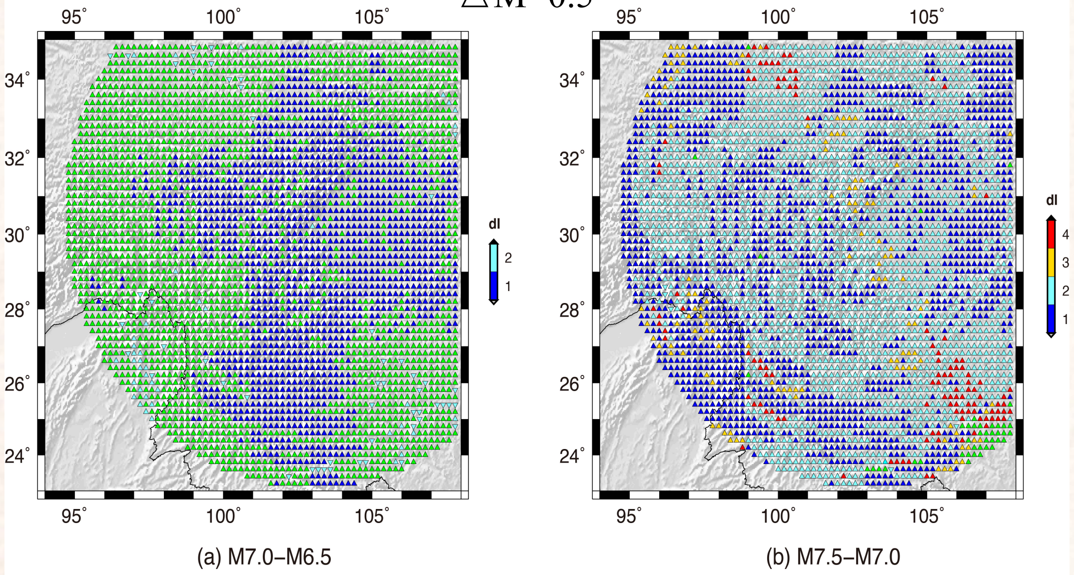


$\triangle M = 0.2$



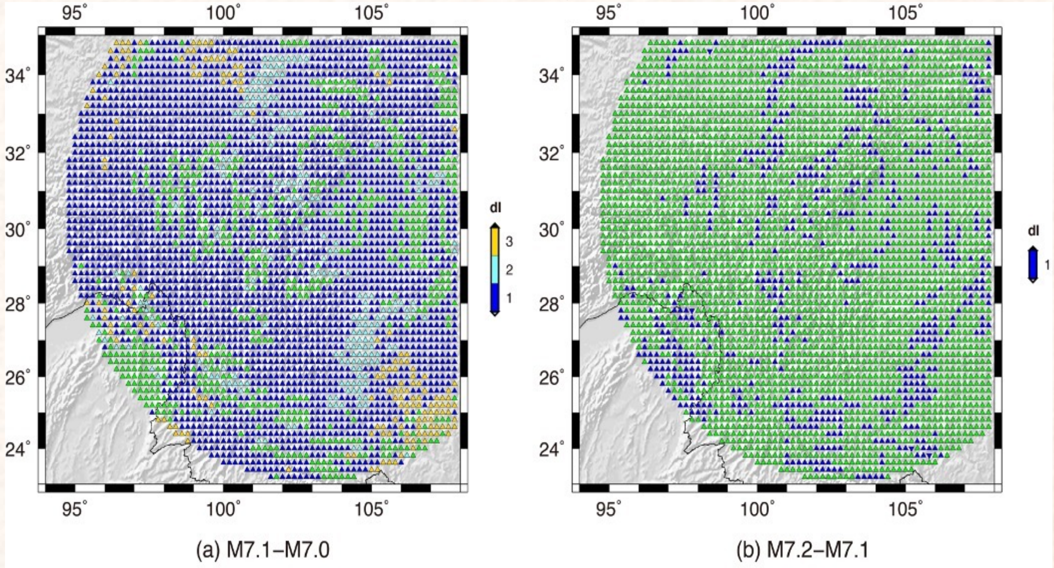
(a) M6.7–M6.5
(b) M7.0–M6.7
(c) M7.2–M7.0
(d) M7.5–M7.2

$\triangle M = 0.5$



(a) M7.0–M6.5
(b) M7.5–M7.0

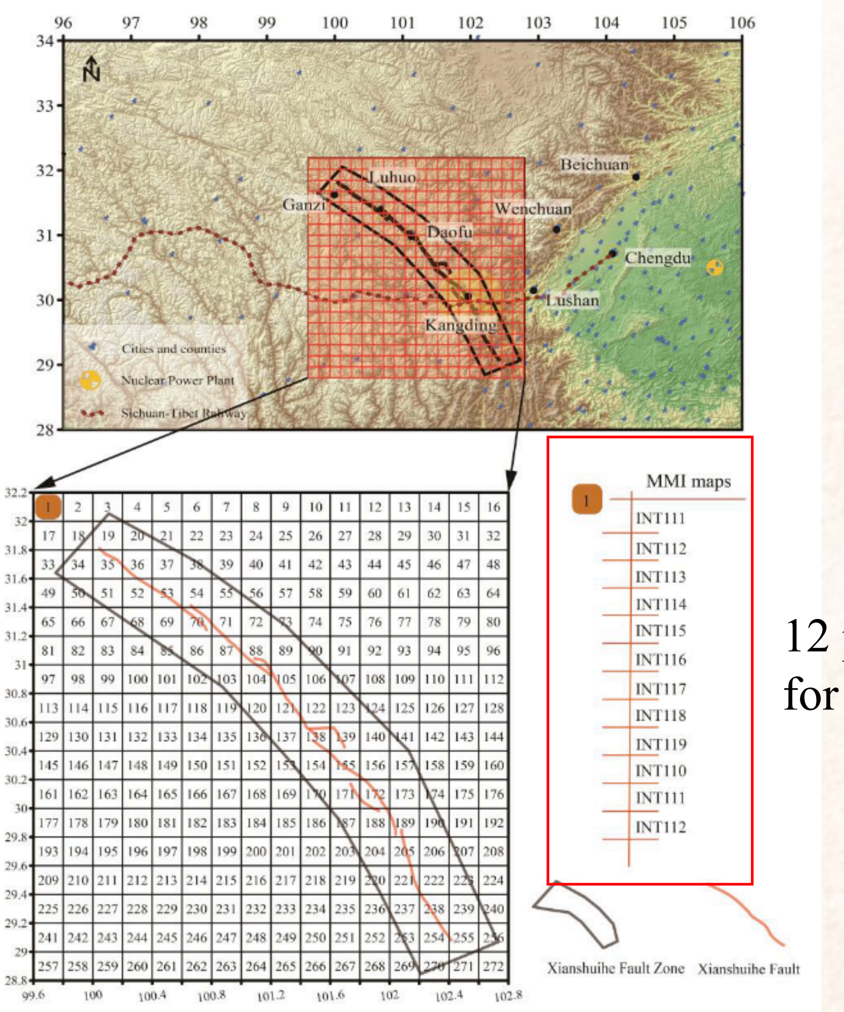
$\triangle M = 0.1$



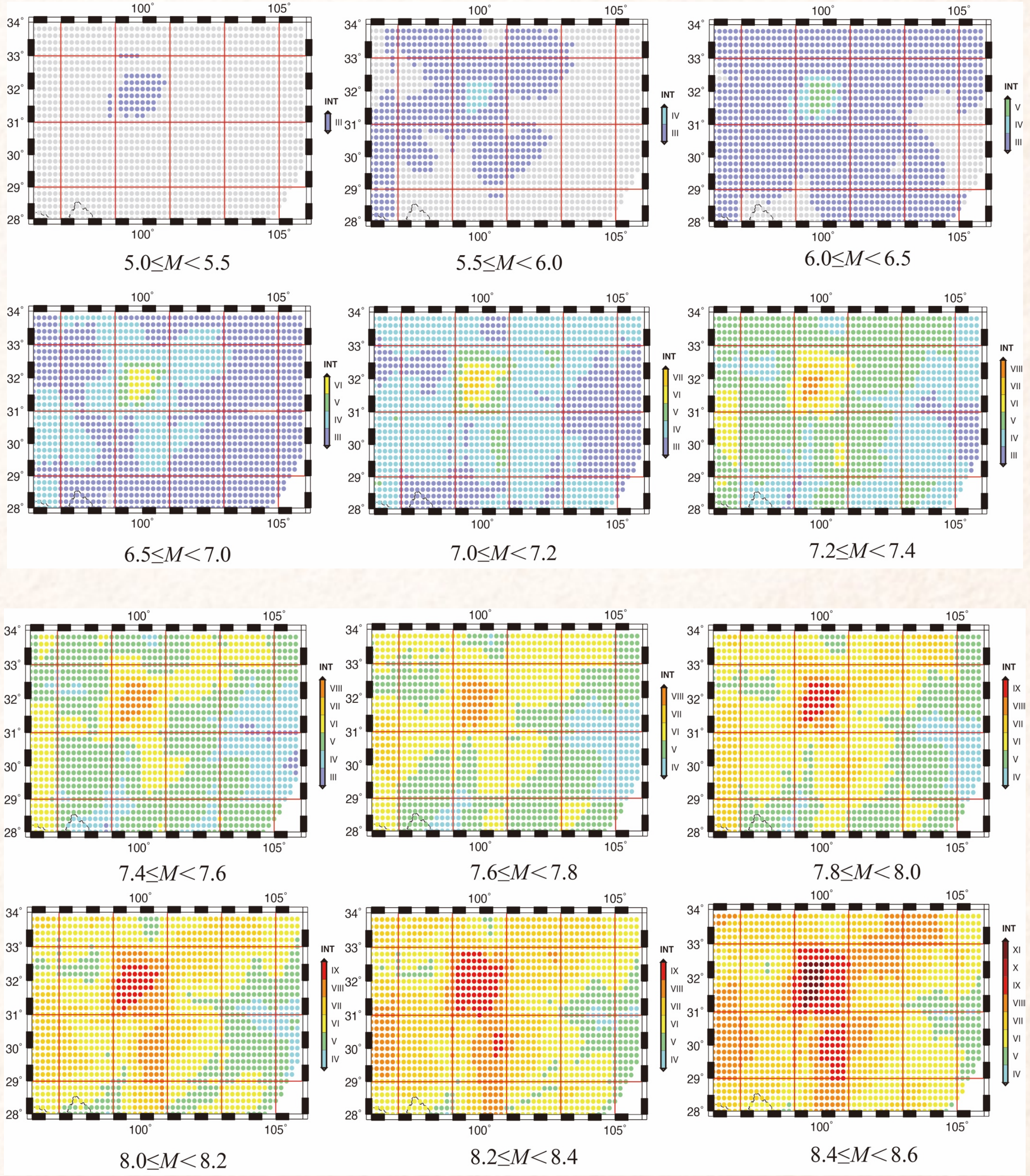
(a) M7.1–M7.0
(b) M7.2–M7.1

4 / Application scenario

Xianshuihe fault in Sichuan-Yunnan region

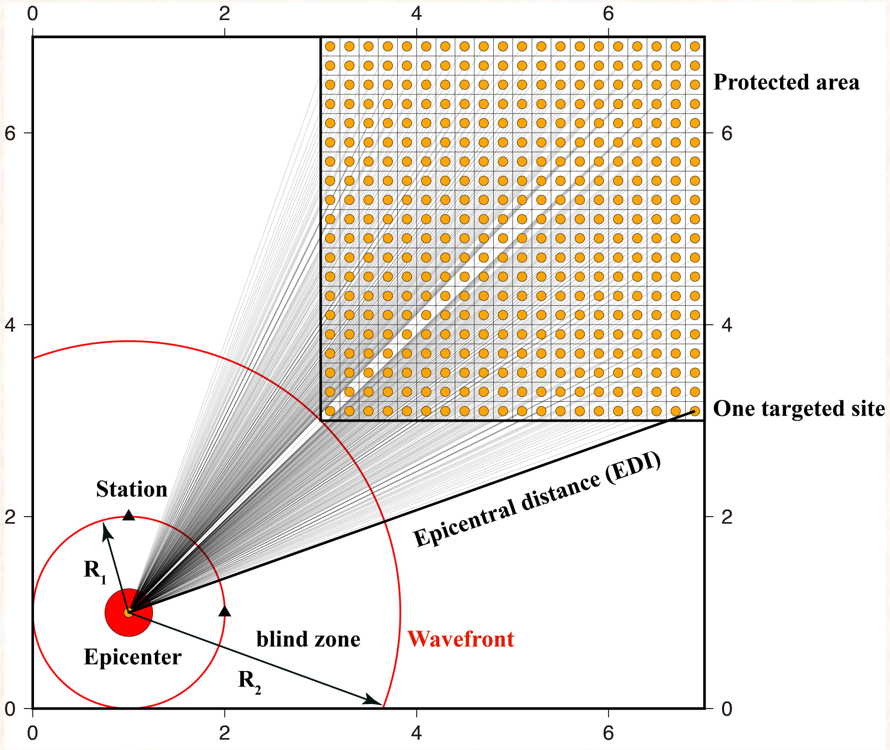


12 possibilities for Intensity

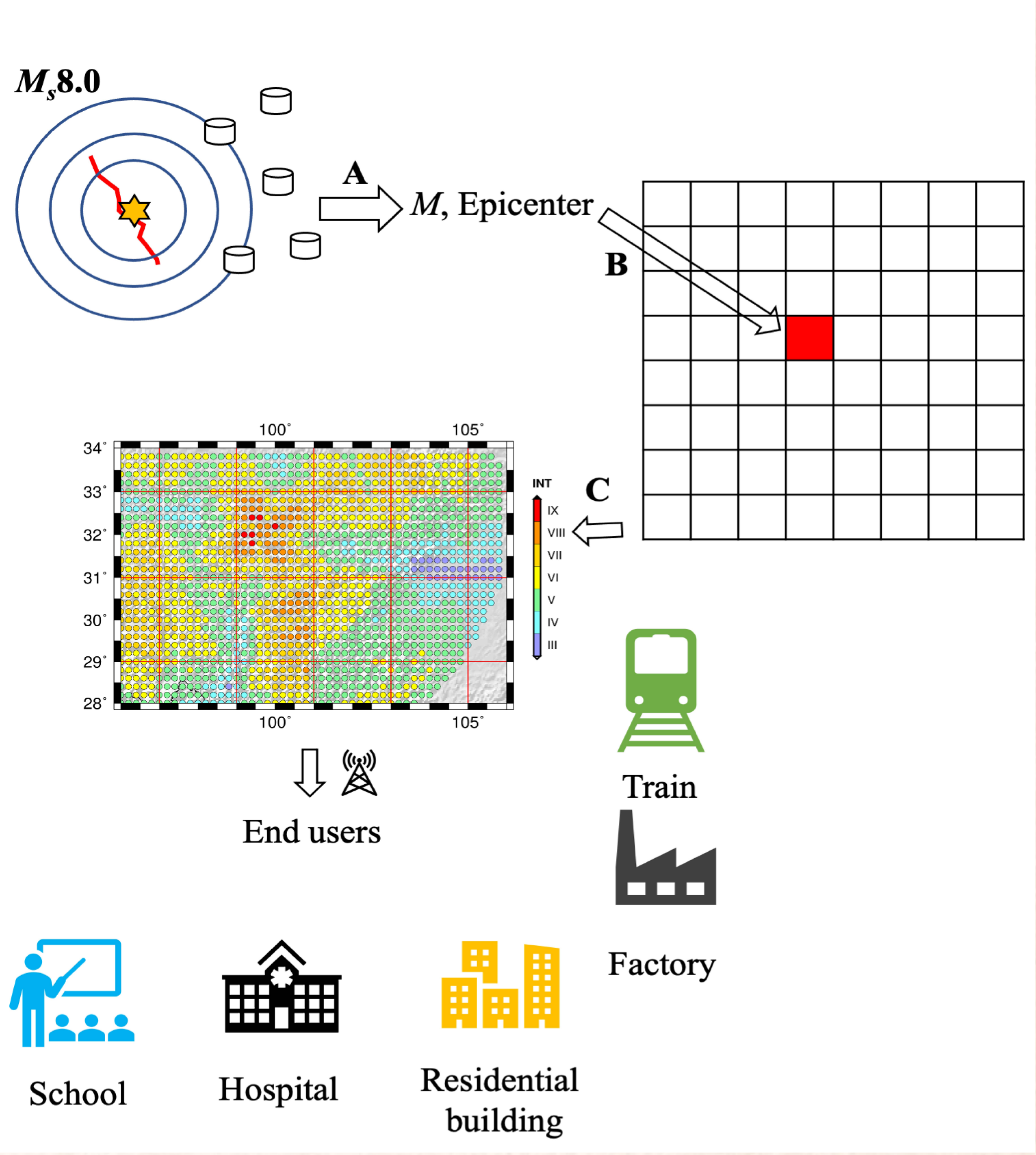


4 / Application scenario

Xianshuihe fault in Sichuan-Yunnan region



Gridded protected area



Conclusions

Considering the peculiarities of NDSHA, its combination with EEW may be developed into two settings: (1) regional SHA tells EEW where the dangerous area is, and then EEW is deployed in that specific area; (2) regional SHA has told EEW where the dangerous area is, and then the adoption of prepared MMI maps (obtained by NDSHA computations considering all possible earthquake scenarios) is a component of EEW in alerting the public. In this work, we limited the discussion of the second setting, assuming XSH as the dangerous area.

Although the new warning mode is still not yet implemented in practice, it already suggests new possibilities for future progresses of EEW, and confirms the usefulness of NDSHA in solidly estimating seismic hazard. As more attention is put into the reduction of seismic and its secondary risks, the proposed EEW empowered by NDSHA will likely play an important role in protecting lives, reducing losses and improving the efficiency of EEW.

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Thanks for your ***comments, suggestions, and criticisms.***

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(2) Zhang Y., Wu, Z. L., Romanelli, F., Vaccari, F., Jiang, C. S., Gao, S. H., Li, J. W., Kossobokov, V. G., Panza, G. F., 2021. Next-generation EEW combined with NDSHA: From concept to implementation. Geosciences, 11, 473. DOI: 10.3390/geosciences11110473.

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