Probabilistic seismic hazard assessment for Taiwan: Application of OpenQuake

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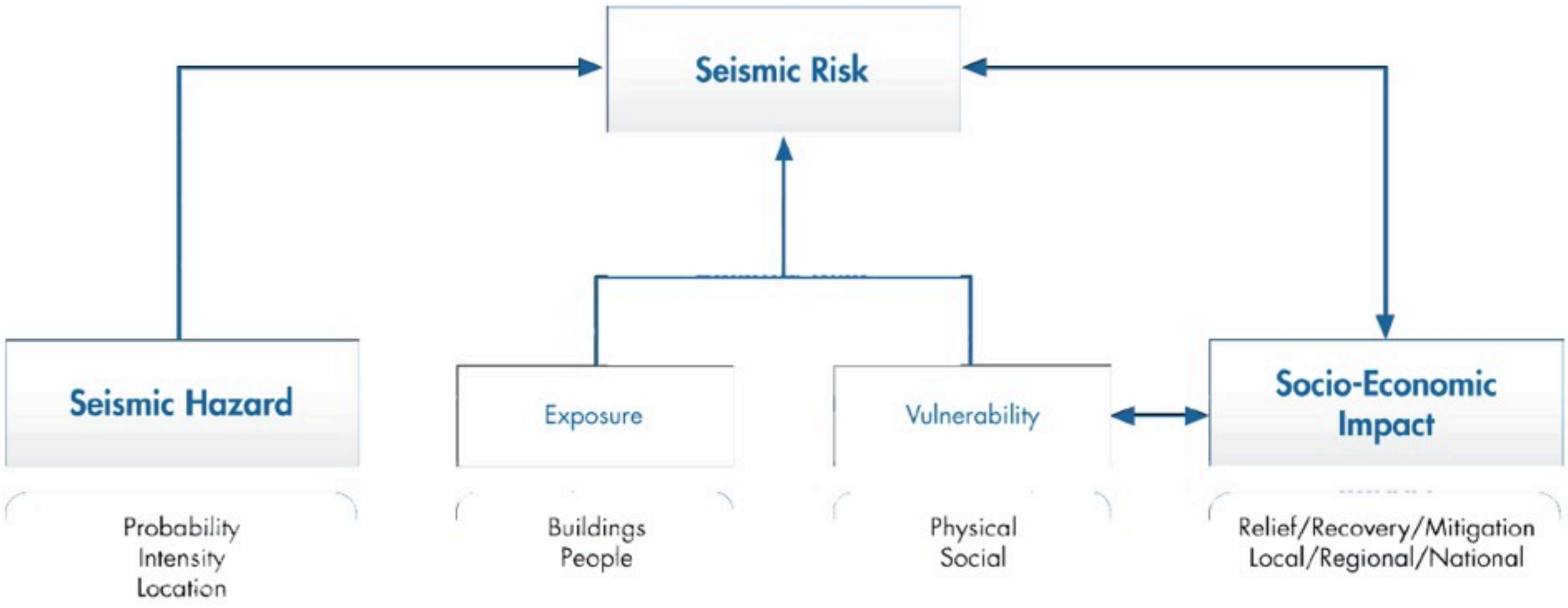
Why GEM?

"A ***collaborative*** effort devised and launched by OECD's Global Science Forum, aimed at engaging the global community in the design, development and deployment of ***state-of-the-art open*** models and tools for ***earthquake risk assessment*** worldwide"

Taiwan has participate GEM since 2012 using the organization '***TEM***'

*OECD: Organisation for Economic Co-operation and Development

Main Modules of GEM



OpenQuake is the corresponding calculation engine

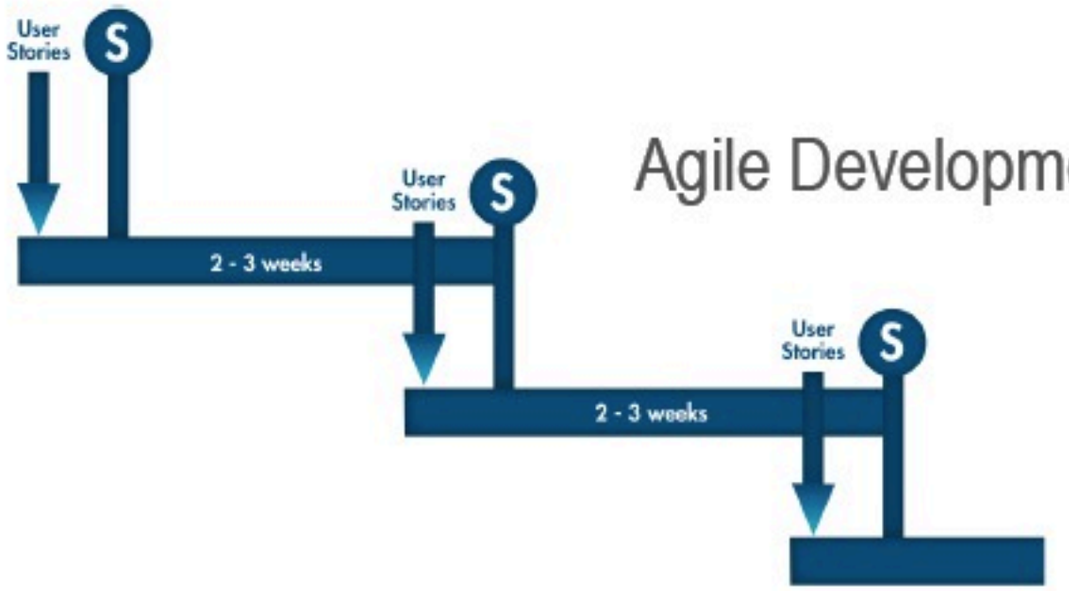
Model facility-Software development

Open Quake

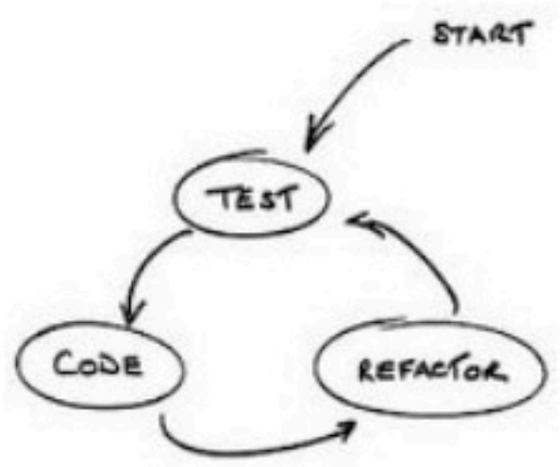
Open Source Development

open source

github
SOCIAL CODING



Agile Development Philosophy



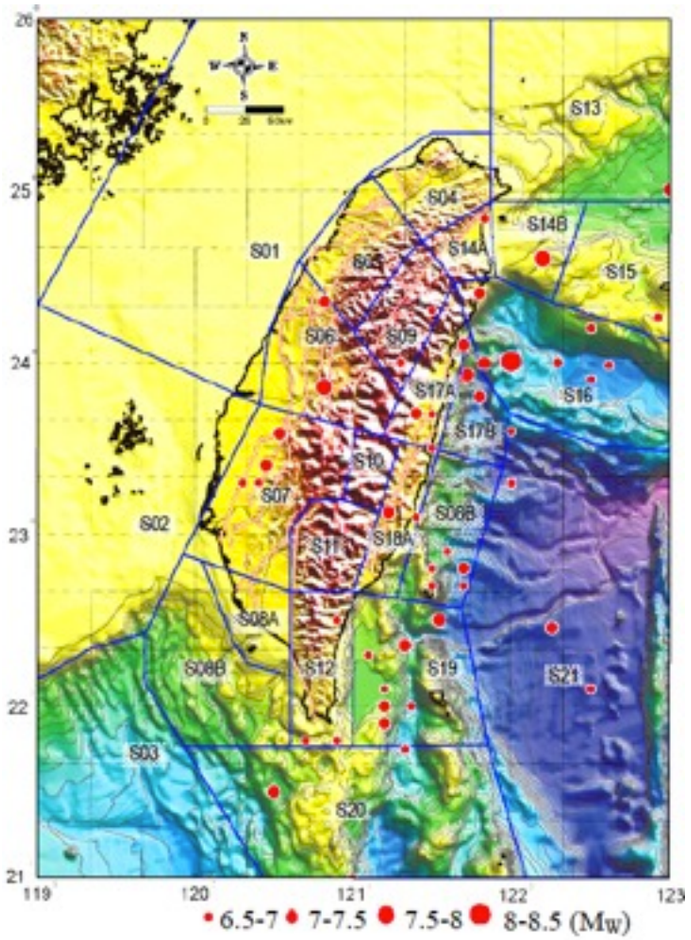
Test Driven Development

Website: http://openquake.org

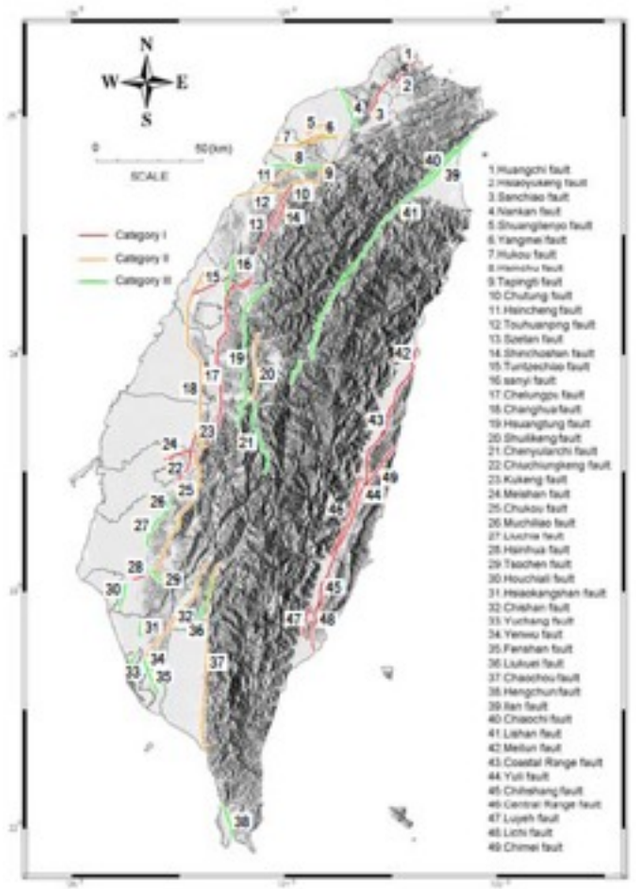
Installation: https://github.com/gem/oq-engine/wiki

Applications…

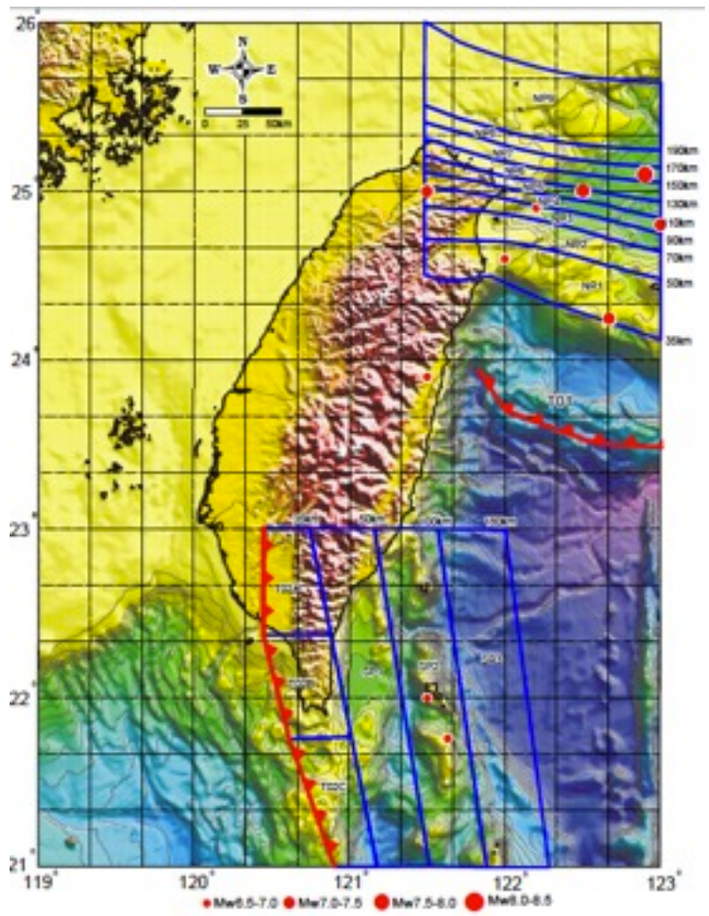
Different ***seismic sources*** are considered



Shallow area source



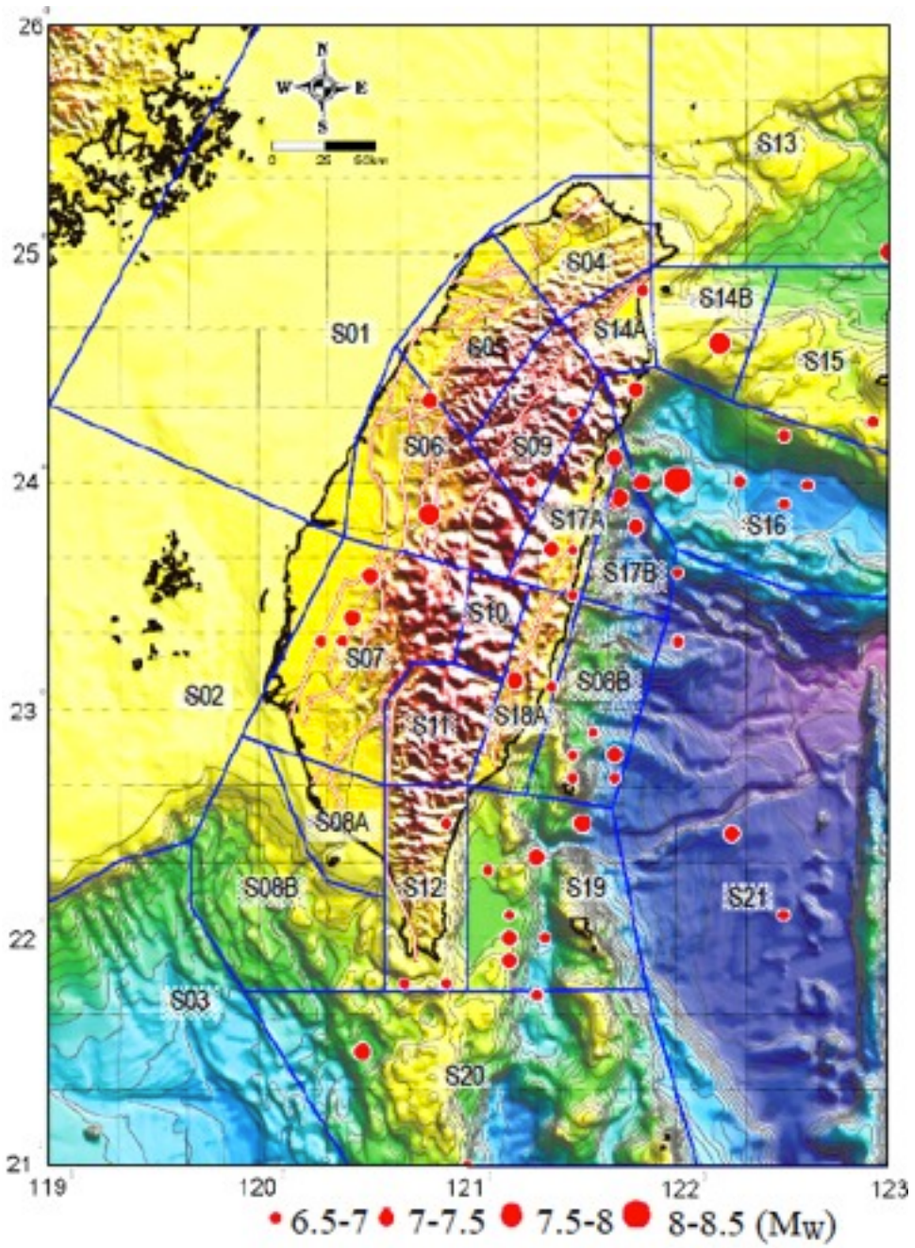
Active fault source

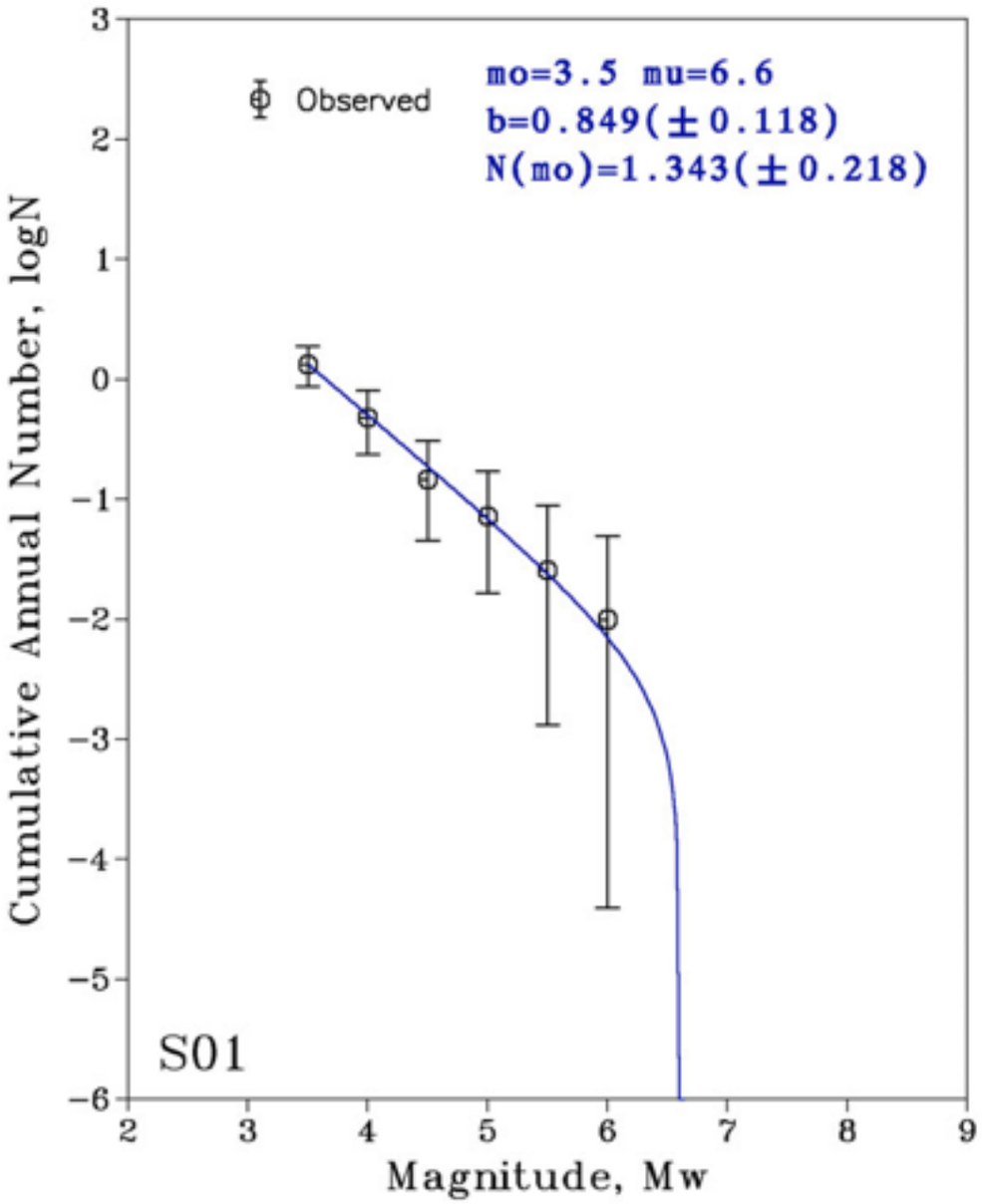


Subduction zone source

After *Cheng et al. (2007)*

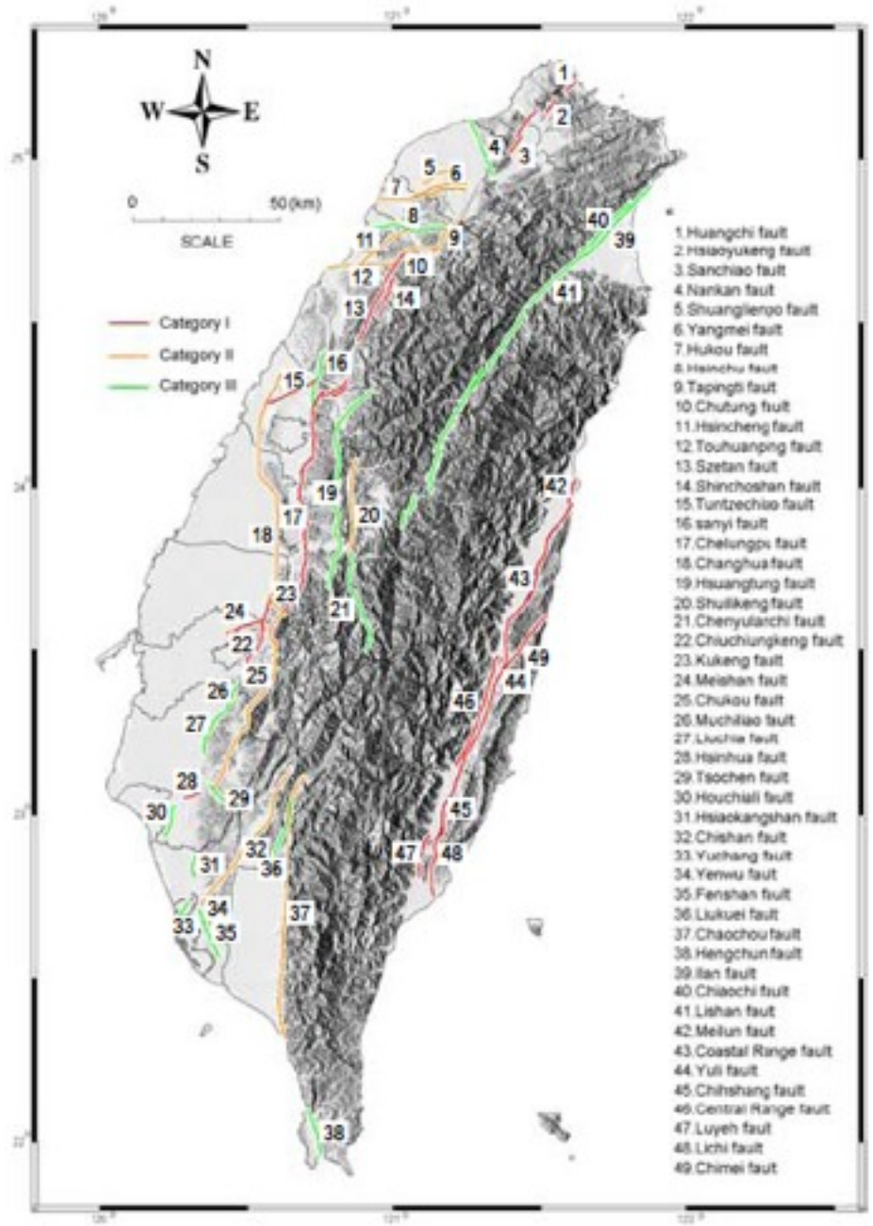
Parameters for the ***shallow area sources***
Treated as ***area sources*** in OpenQuake

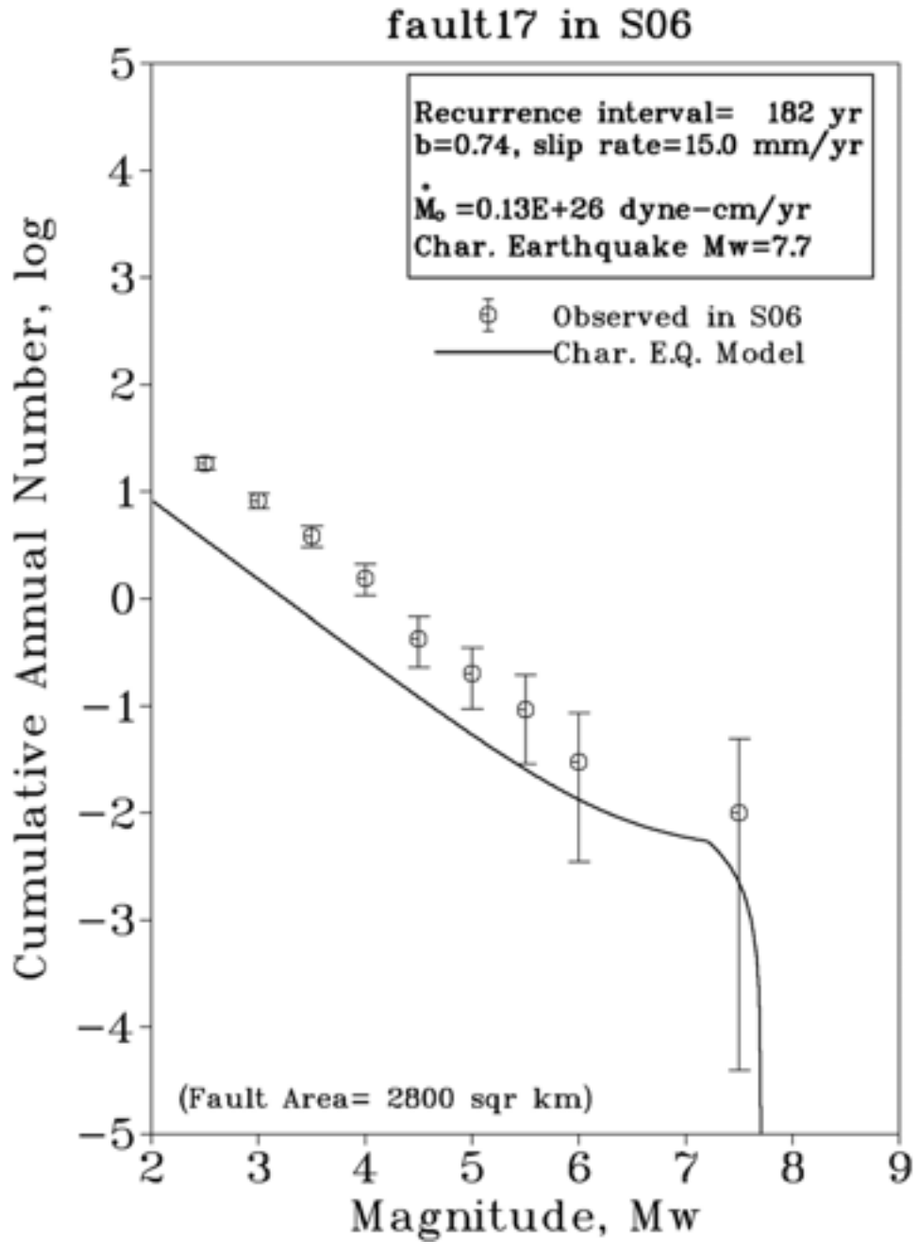




The truncated exponential model is considered.

Parameters for the ***active fault sources***
Treated as ***simple fault sources*** in OQ





The characteristic earthquake model is considered.

built-in GSIMs…

GSIMs are ***usually*** called from the ***build-in library***

Ground-shaking intensity models

Package `openquake.hazardlib.gsim` contains base and specific implementations of ground shaking intensity models. See `openquake.hazardlib.gsim.base`.

Built-in GSIMs ¶

- Abrahamson and Silva 2008
- Akkar and Bommer 2010
- Akkar and Cagnan 2010
- Atkinson and Boore 2003
- Atkinson and Boore 2006
- Boore and Atkinson 2008
- Campbell 2003
- Cauzzi and Faccioli 2008
- Chiou and Youngs 2008
- Faccioli et al. 2010
- Lin and Lee 2008
- Sadigh et. al. 1997
- Si and Midorikawa 1999
- Toro et al. 2003
- Youngs et al. 1997
- Zhao et al. 2006

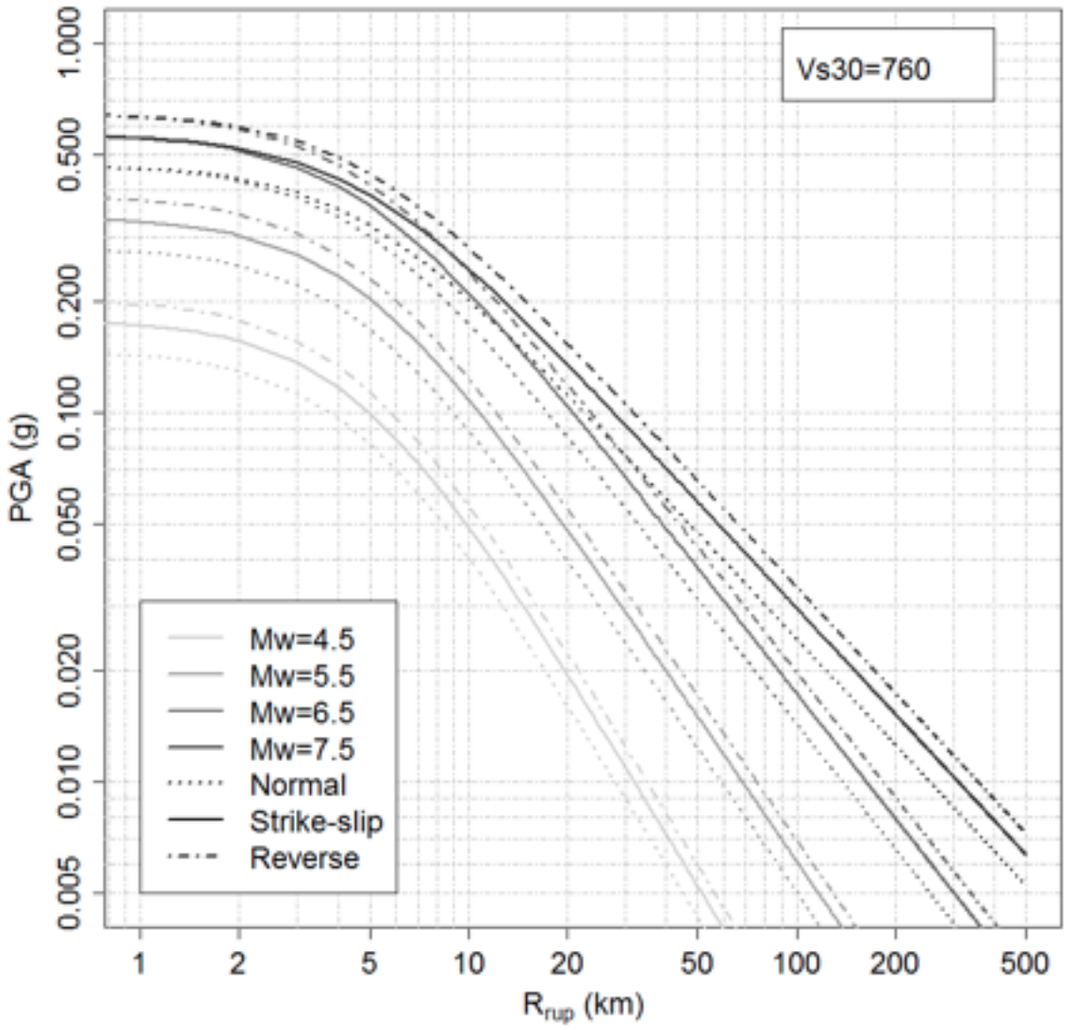
Considered ***GSIMs by Lin & Lee (2008)*** for the subduction zone sources

Base GSIM classes and functionality

Module `openquake.hazardlib.gsim.base` defines base classes for different kinds of `ground shaking intensity models`.

Considered ***GSIMs by Lin (2009)*** for the crustal sources

A ***user*** becomes a ***contributor***!



$$\ln y = C_1 + F_1 + C_3(8.5 - M_W)^2 + (C_4 + C_5(M_W - 6.3))\ln(\sqrt{(R^2 + \exp(H)^2)})$$

$$C_6 F_{NM} + C_7 F_{RV} + C_8 \ln(Vs_{30}/1130)$$

$$\begin{cases} F_1 = C_2(M_W - 6.3) & Where \quad M_W \le 6.3 \\ F_1 = (-H \cdot C_5)(M_W - 6.3) & Where \quad M_W > 6.3 \end{cases}$$

Created code for OpenQuake input

▼

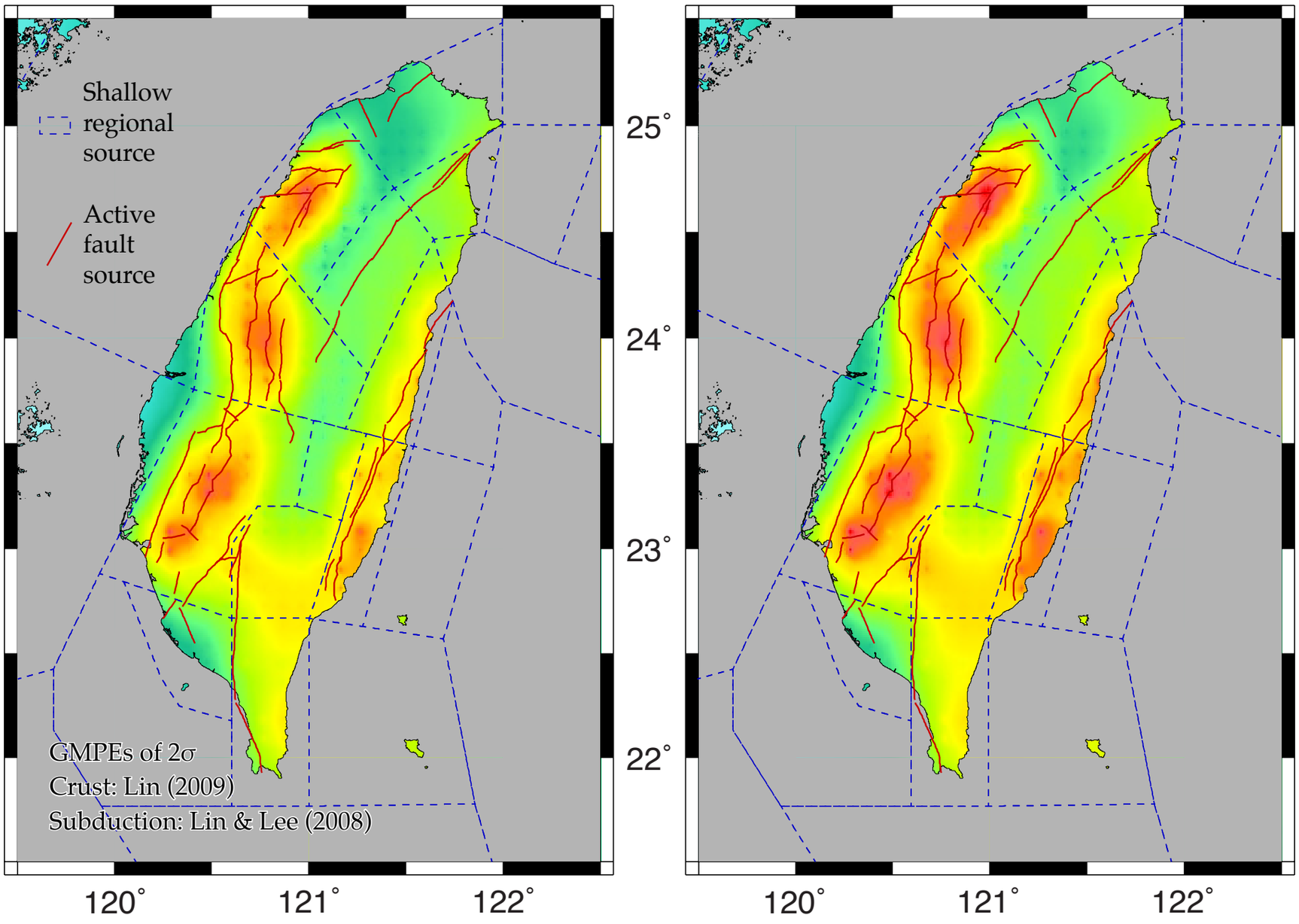
```
# The Hazard Library
# Copyright (C) 2012 GEM Foundation & Chung-Han Chan
#
# This program is free software: you can redistribute it and/or modify
# it under the terms of the GNU Affero General Public License as
# published by the Free Software Foundation, either version 3 of the
# License, or (at your option) any later version.
#
# This program is distributed in the hope that it will be useful,
# but WITHOUT ANY WARRANTY; without even the implied warranty of
# MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
# GNU Affero General Public License for more details.
#
# You should have received a copy of the GNU Affero General Public License
# along with this program.  If not, see <http://www.gnu.org/licenses/>.
"""
Module exports :class:`Lin2009`
"""
from __future__ import division

import numpy as np

from nhlib.gsim.base import GMPE, CoeffsTable
from nhlib import const
from nhlib.imt import PGA, SA

class Lin2009(GMPE):
    """
    Implements GMPE developed by Po-Shen Lin and published as "Ground-motion
    attenuation relationship and path-effect study using Taiwan Data set"
    (Ph.D. dissertation of National Central University, Taiwan).
    This class implements the equations for 'crustal events'.
    """

    #: Supported tectonic region type is active shallow crust.
    DEFINED_FOR_TECTONIC_REGION_TYPE = const.TRT.ACTIVE_SHALLOW_CRUST
```

PSHA results…

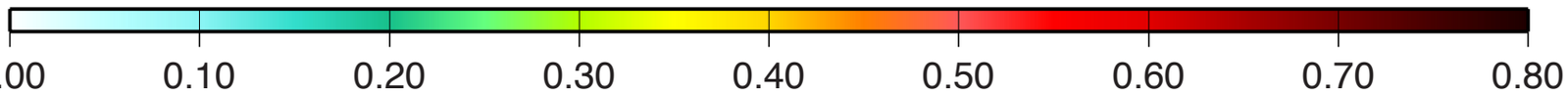
High hazards along the active faults in both east & west Taiwan

Probability of exceedance of 10 % in 50 yrs

Probability of exceedance of 2 % in 50 yrs

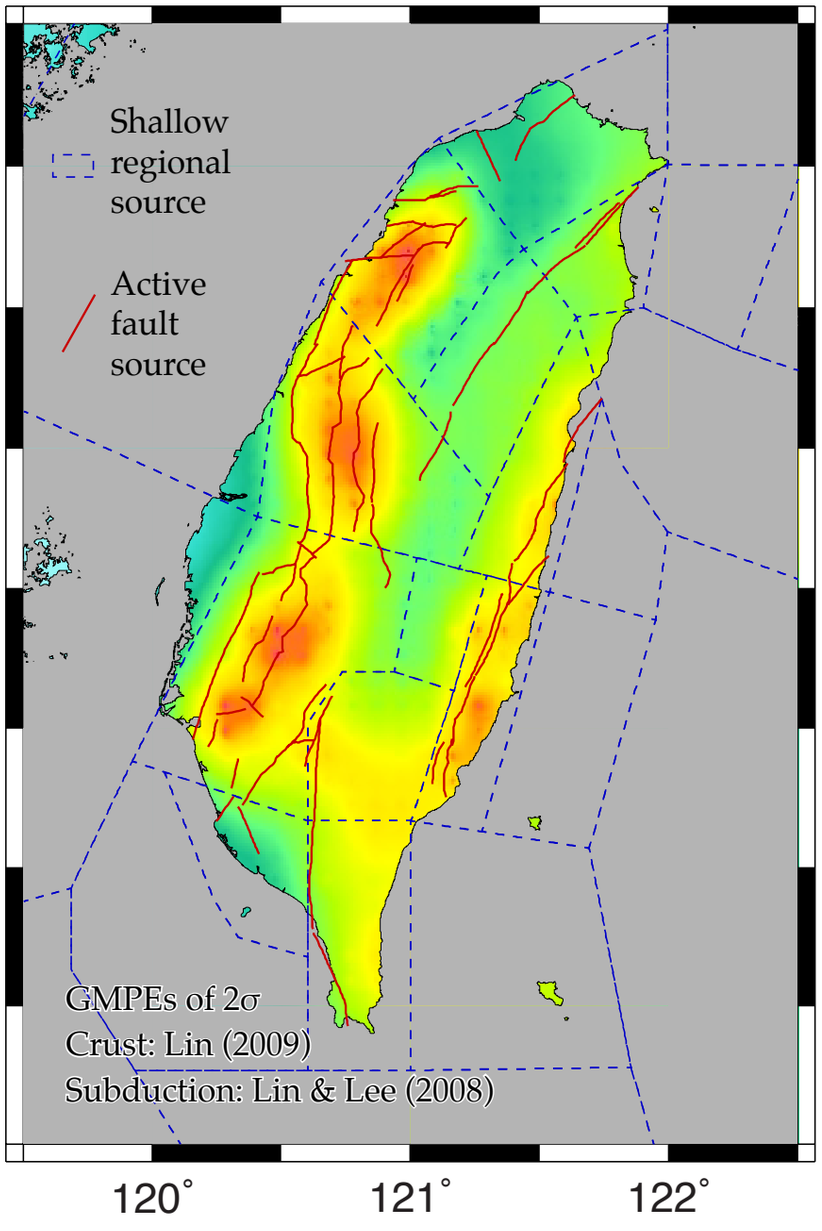


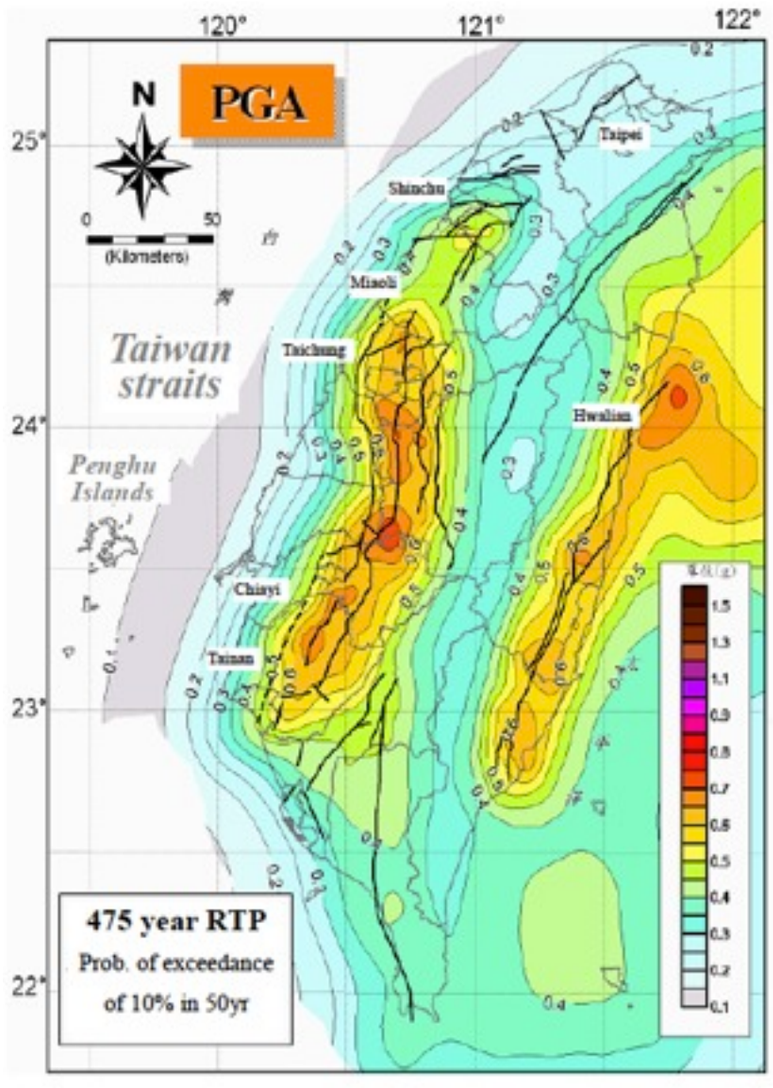
Seismic hazard map generated by OpenQuake (PGA, in g)



Similar results as those by *Cheng et al.* (2007)
Possible further application for TEM parameters

Probability of exceedance of 10 % in 50 yrs



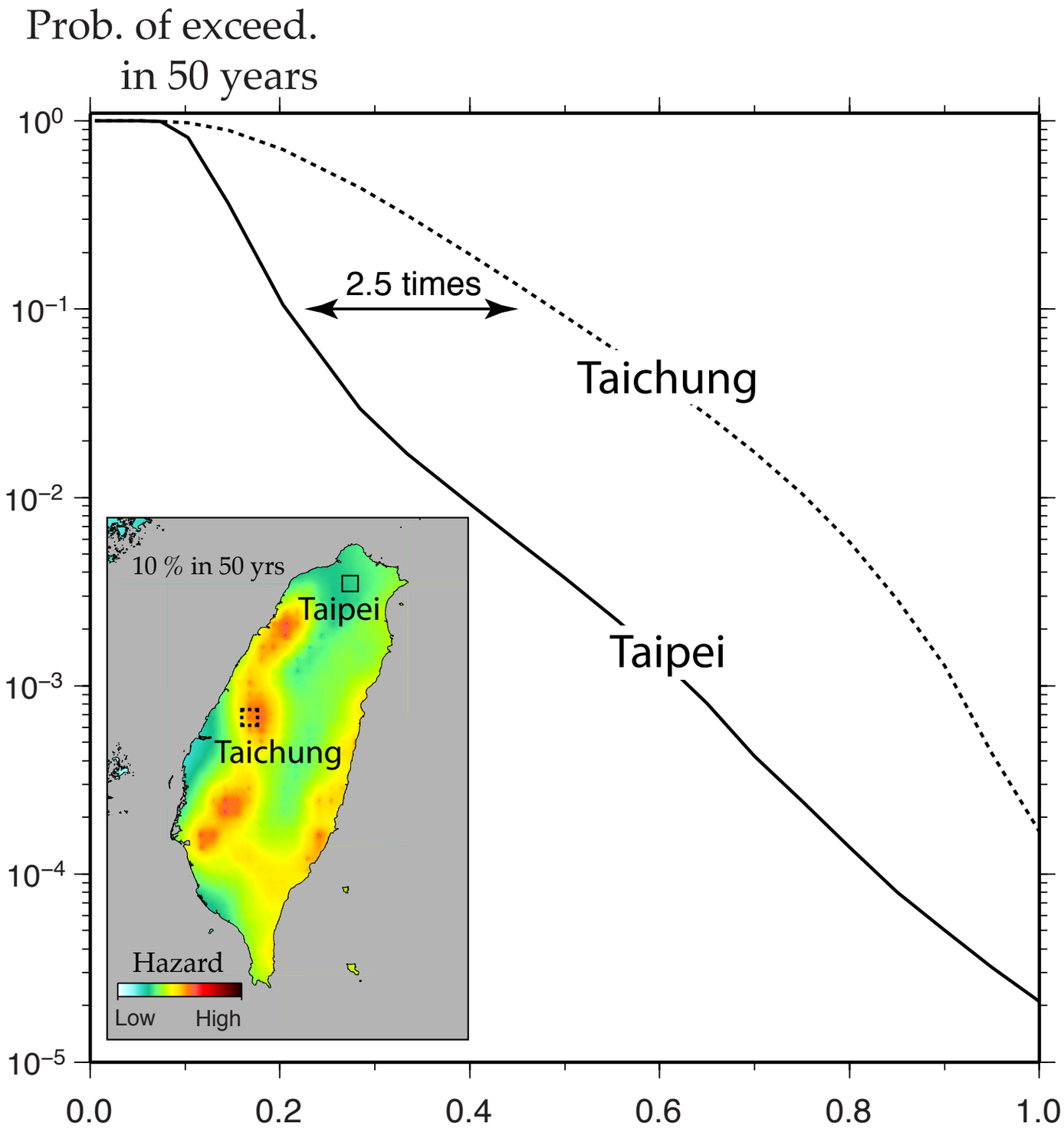


Cheng et al. (2007) result

Seismic hazard map generated by OpenQuake (PGA, in *g*)

Hazard curves…

PSHA in terms of ***hazard curves***



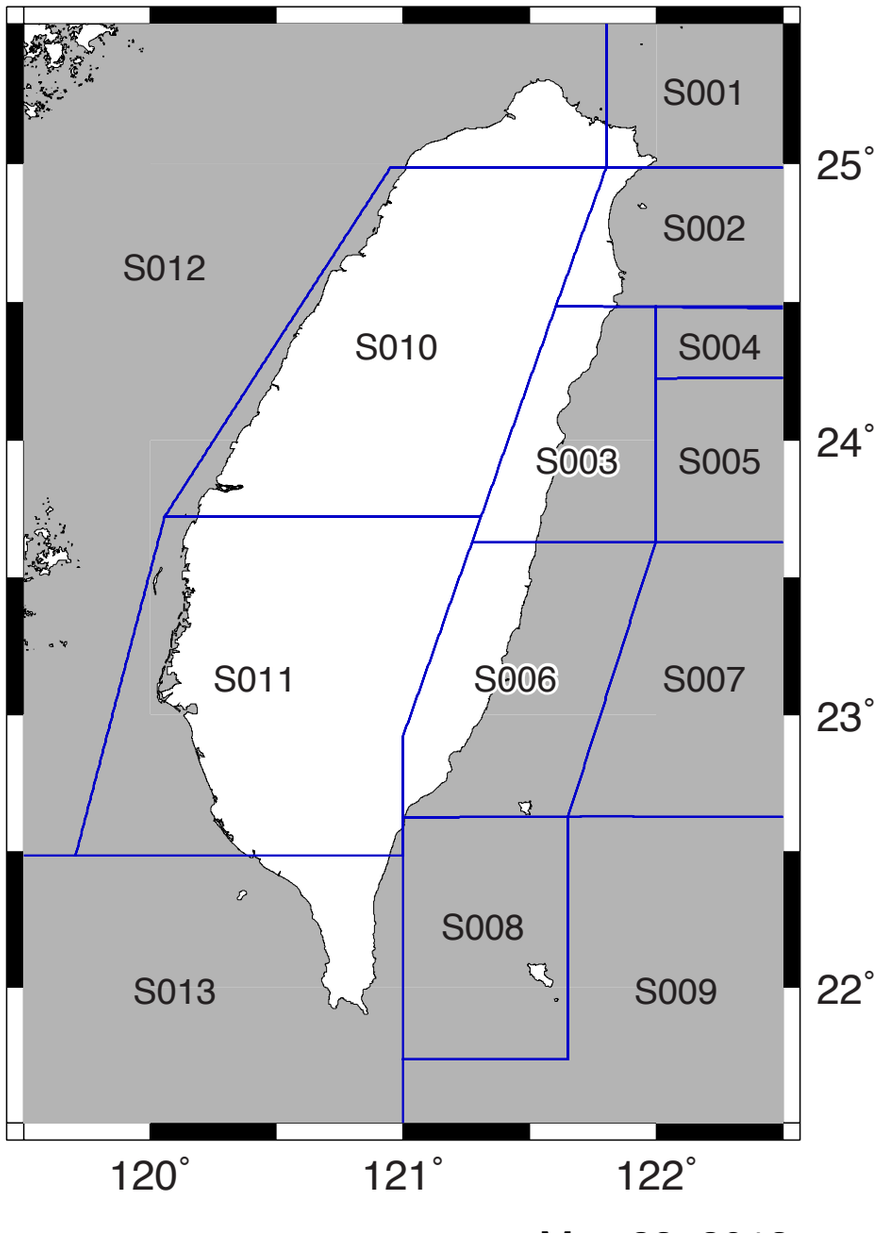
Updated TEM components…

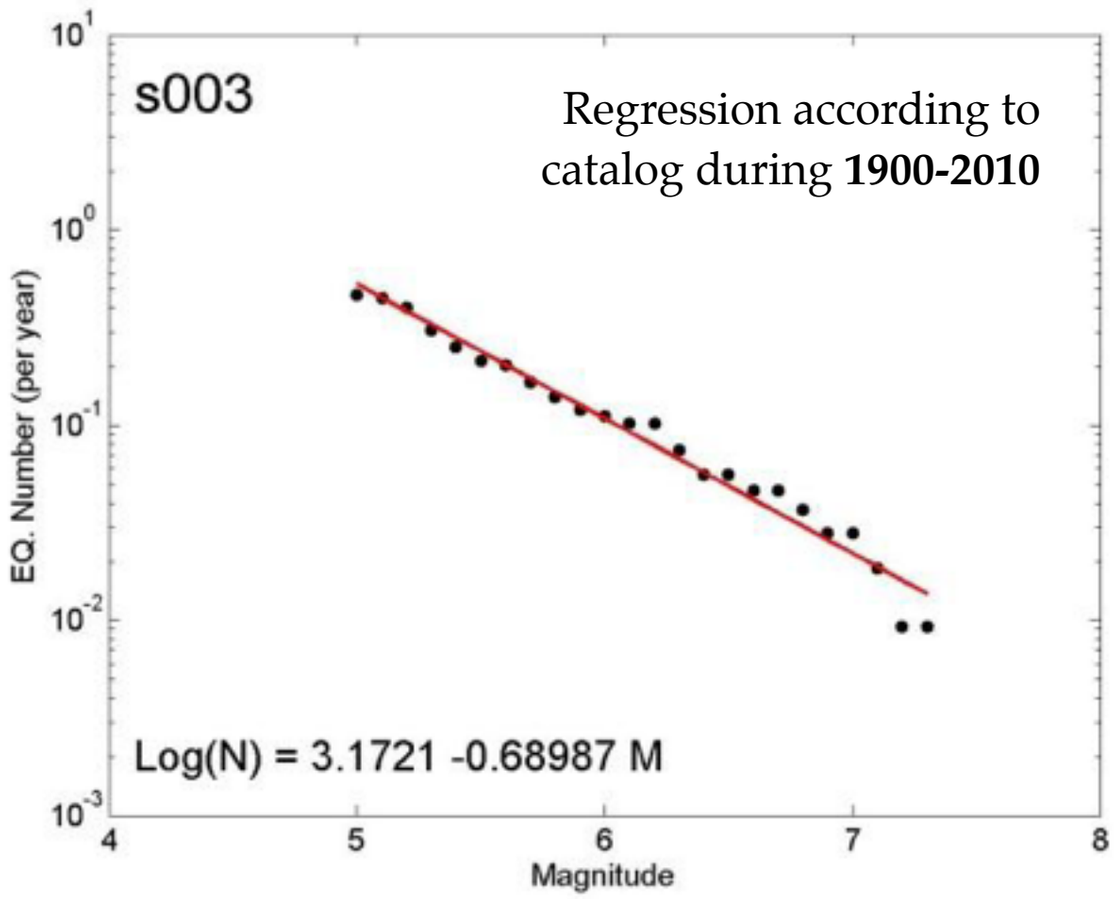
Implement the ***state-of-the-art*** parameters from ***TEM***

- Updated shallow sources
  - obtained by Prof. Kuo-Liang Wen
- Different ground shaking intensity models
  - obtained by Dr. Yating Lee (poster in this Workshop)

Parameters for the ***shallow area sources***

Treat as ***area sources*** in OpenQuake





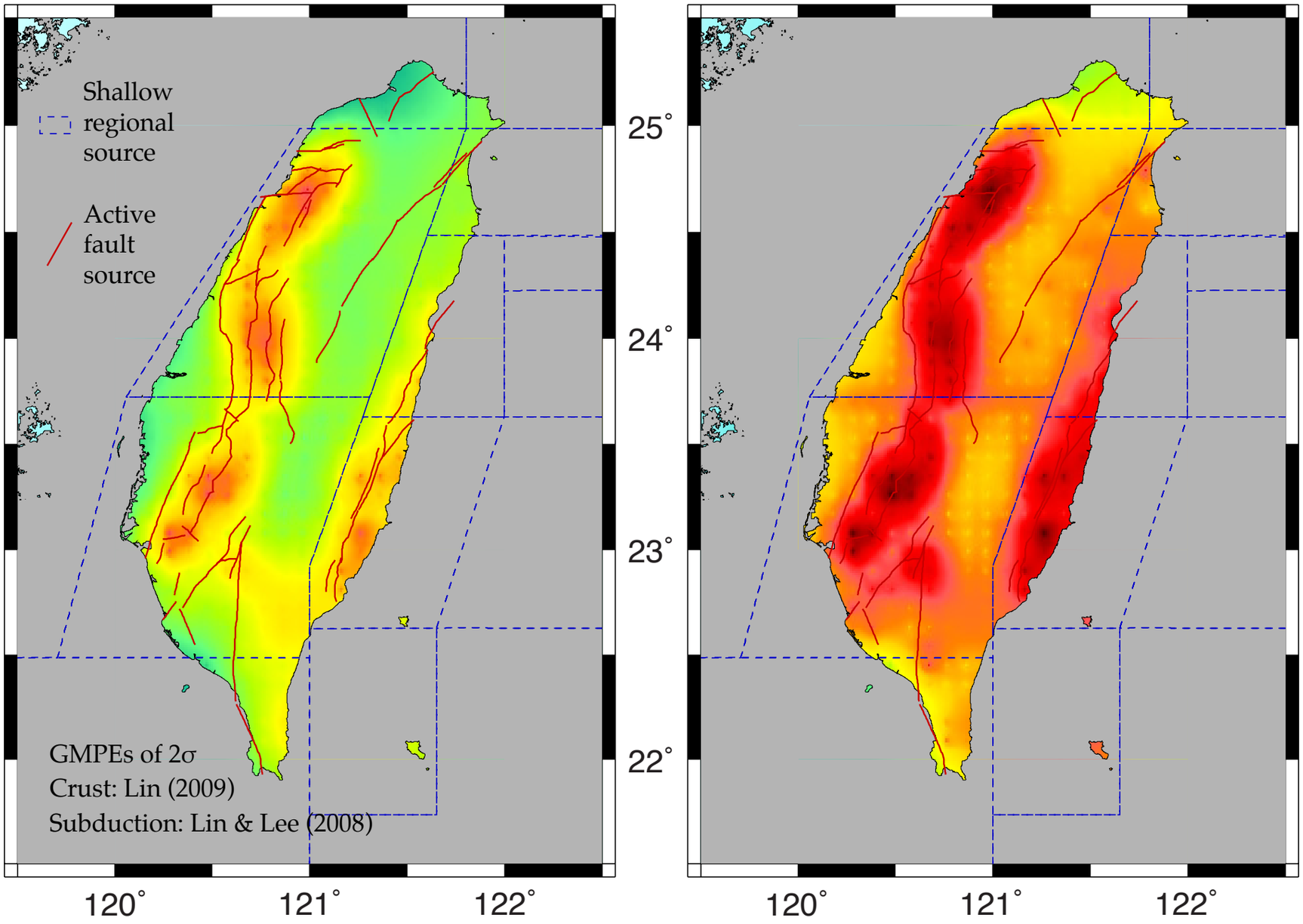
The truncated exponential model is considered.

PSHA results…

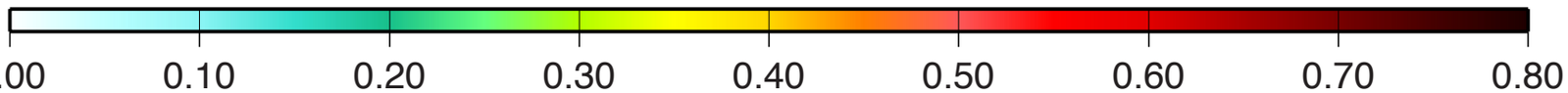
High hazards along the active faults in both east & west Taiwan

Probability of exceedance of 10 % in 50 yrs

Probability of exceedance of 2 % in 50 yrs



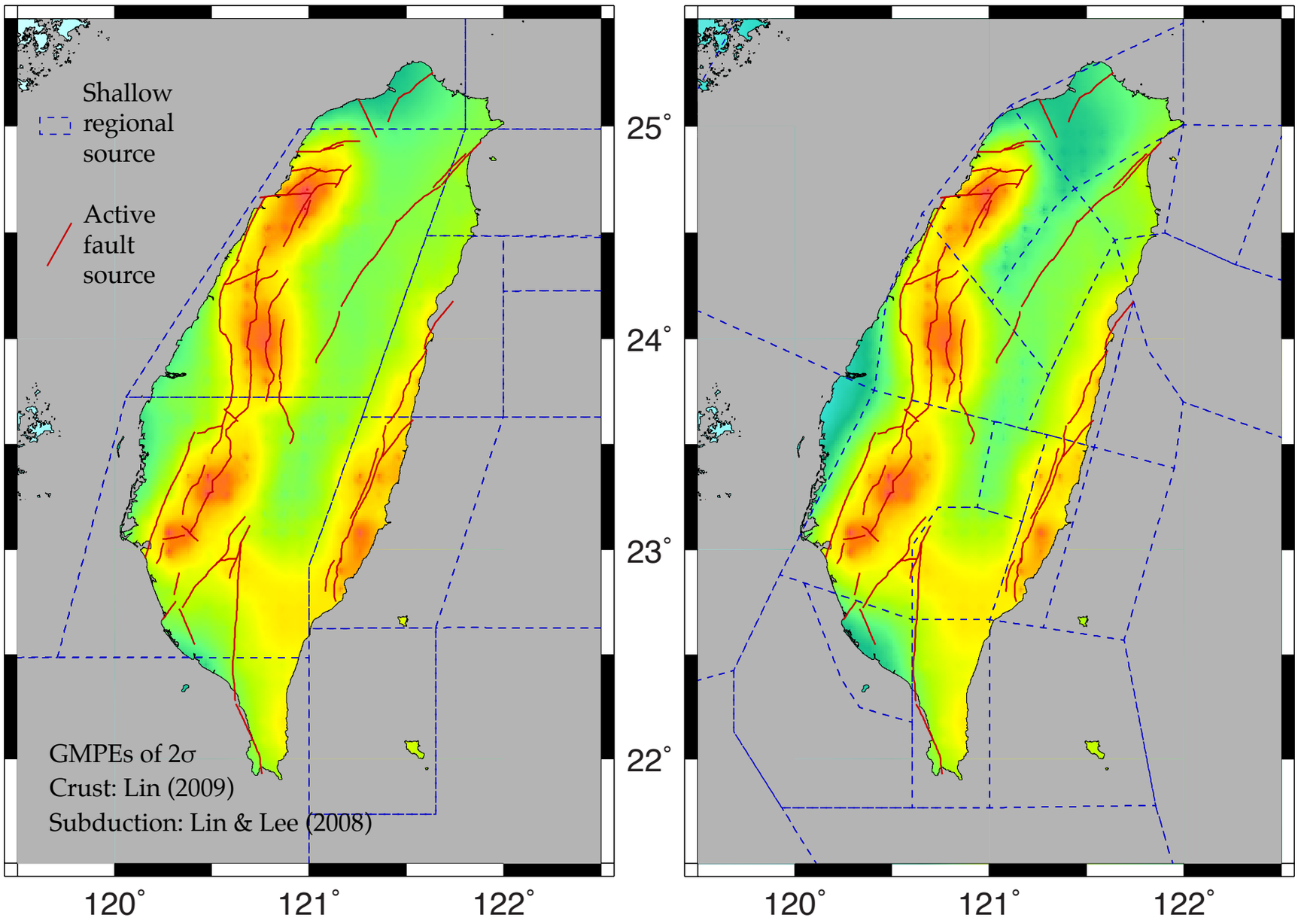
Seismic hazard map generated by OpenQuake (PGA, in g)



Similar patterns, ***smoother*** results based on the ***Wen's parameters***

Shallow sources by Prof. Wen

Shallow sources by Dr. Cheng

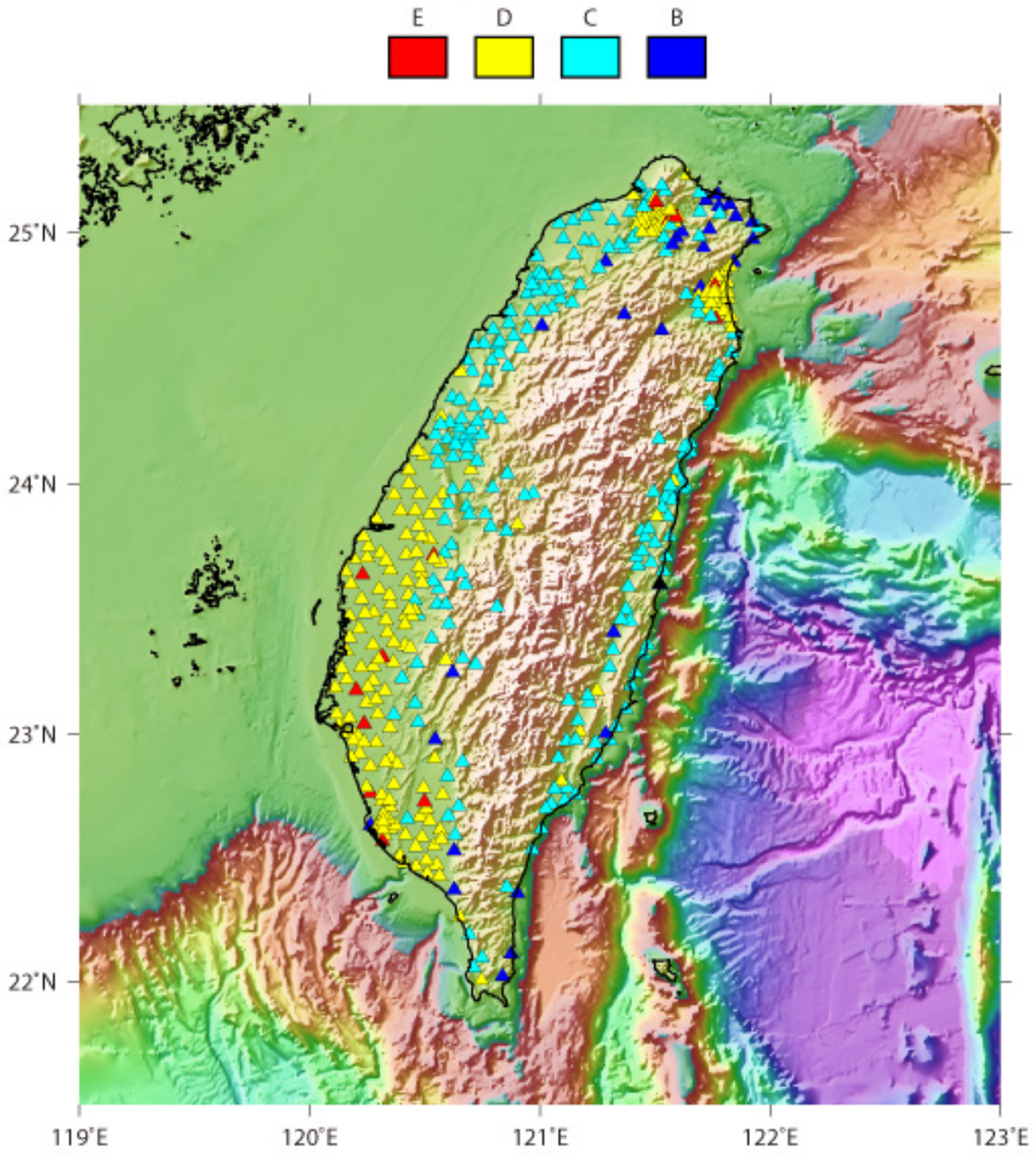


Seismic hazard map generated by OpenQuake (PGA, 10% in 50 yrs in *g*)

0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80

GSIMs by Lee…

Ground motion behaviors in form of ***shaking duration***



$$\log(\tau) = 0.2926 M_E - 0.0009\Delta - 0.6802 \pm 0.2450 \quad \text{for all site classes;}$$

$$\log(\tau) = 0.3520 M_E - 0.0024\Delta - 1.1246 \pm 0.2324 \quad \text{for site class B;}$$

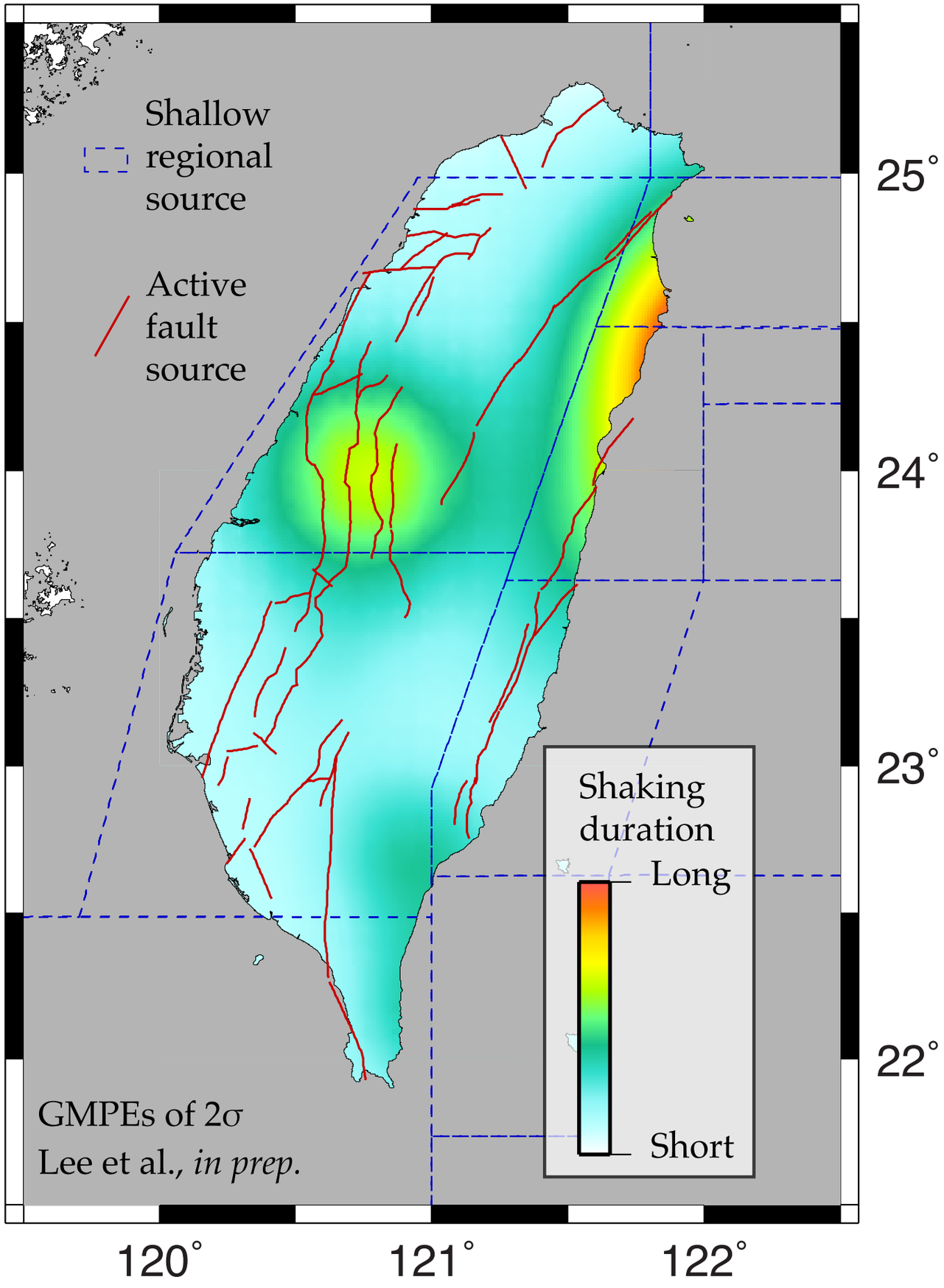
$$\log(\tau) = 0.2985 M_E - 0.0010\Delta - 0.7719 \pm 0.2239 \quad \text{for site class C;}$$

$$\log(\tau) = 0.4067 M_E - 0.0018\Delta - 1.2293 \pm 0.2396 \quad \text{for site class D;}$$

$$\log(\tau) = 0.6190 M_E - 0.0025\Delta - 2.5024 \pm 0.2497 \quad \text{for site class E.}$$

After *Lee et al.* (poster in this Workshop)

PSHA results…



High hazards along the active faults of west Taiwan & the northeast coast

Future works…

Future works

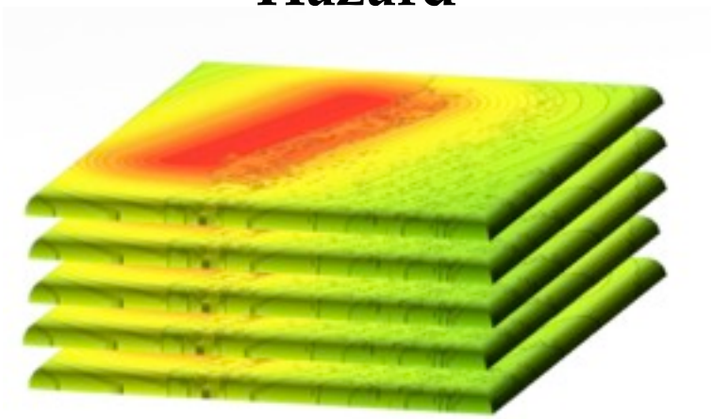
- Implement the ***state-of-the-art*** parameters from ***TEM***
  - Active fault parameters (*Cheng et al.*, poster in this Workshop)
  - Historical earthquake catalog (*Shyu et al.*, poster in this Workshop)
  - Ground shaking model (*Lin et al.* and *Wen et al.*, orals in this Workshop)

- Consider ***time-dependency***
  - Both long-term and short-term (*Chan et al.*, poster in this Workshop)

- Further assess seismic risk
  - When ***exposure*** & ***vulnerability*** parameters are available

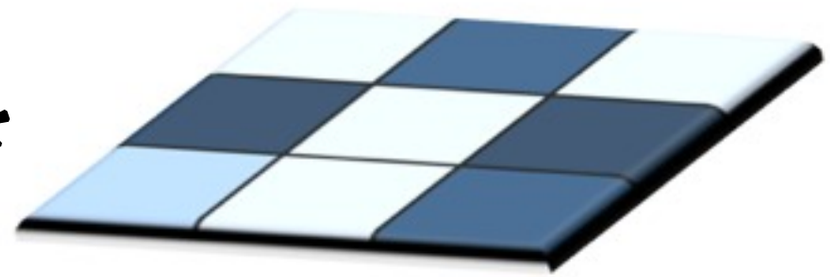
Probabilistic seismic risk assessment impact can be implemented according to the results of PSHA

Hazard



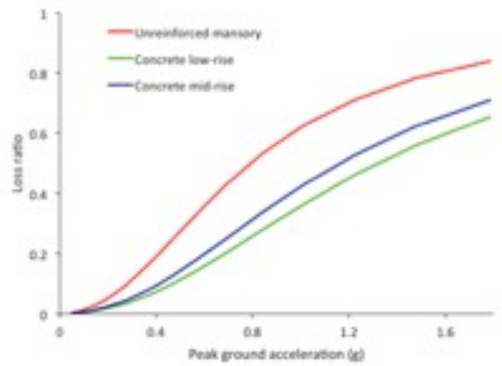
*

Exposure

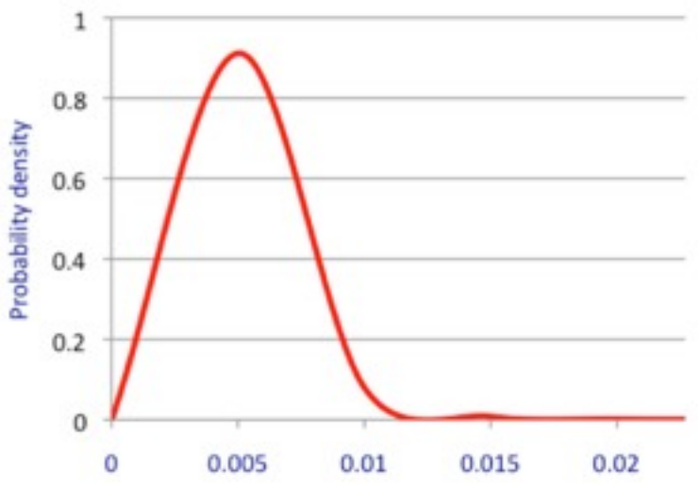


*

Vulnerability

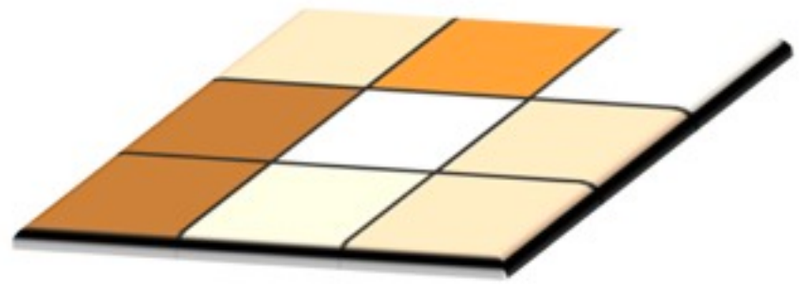


Loss curve



or / and

Loss map



TEM needs OpenQuake!

OpenQuake needs TEM!

Definitions of duration

M=5.5; D=27km (Dc=56.3km)

- **Bracketed duration**

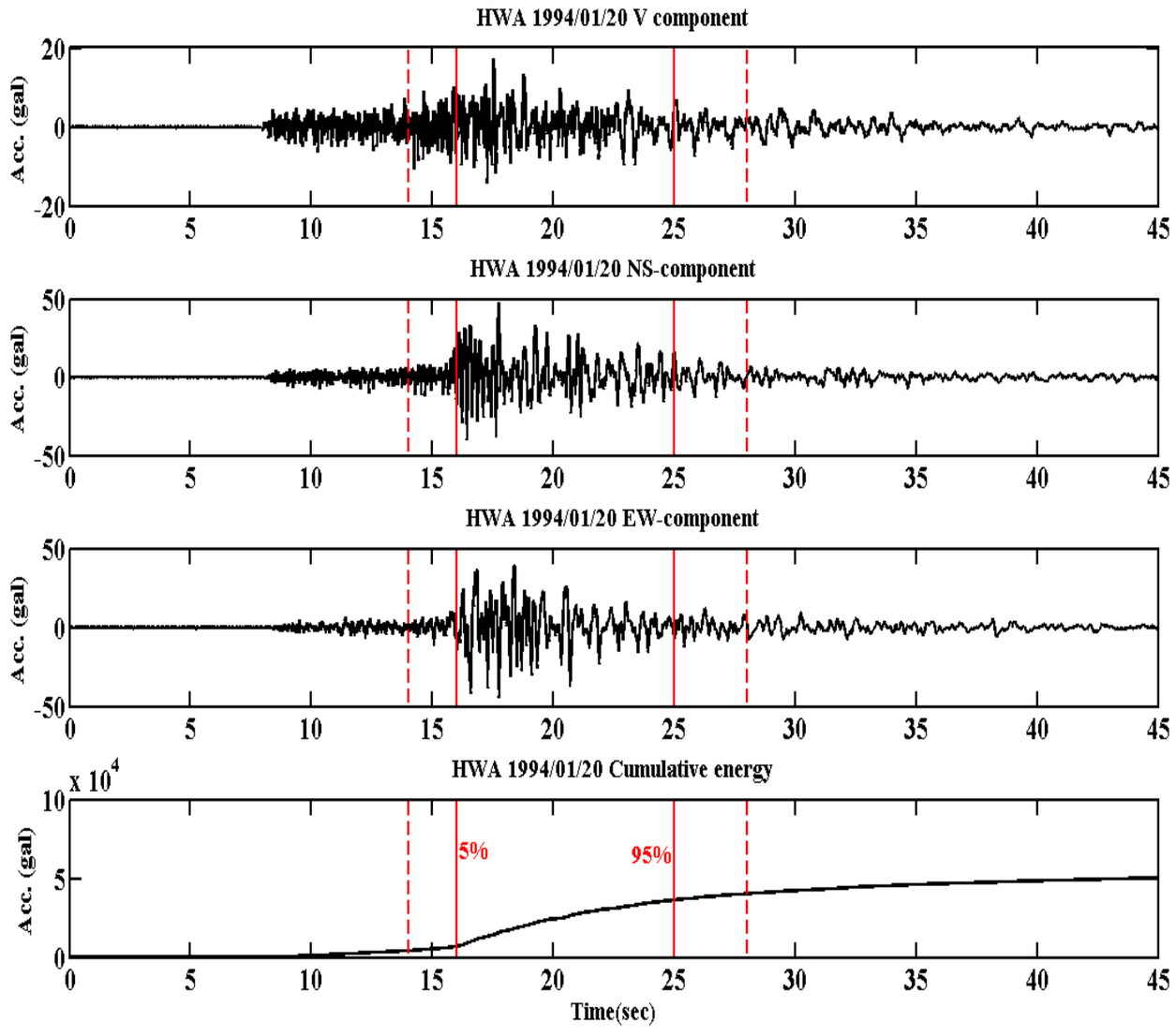
[Bolt(1973) and Page et al. (1975)]

- **Significant duration**

[Husid et al. (1969) and Trifunac and Brady (1975)]

- **This study :**

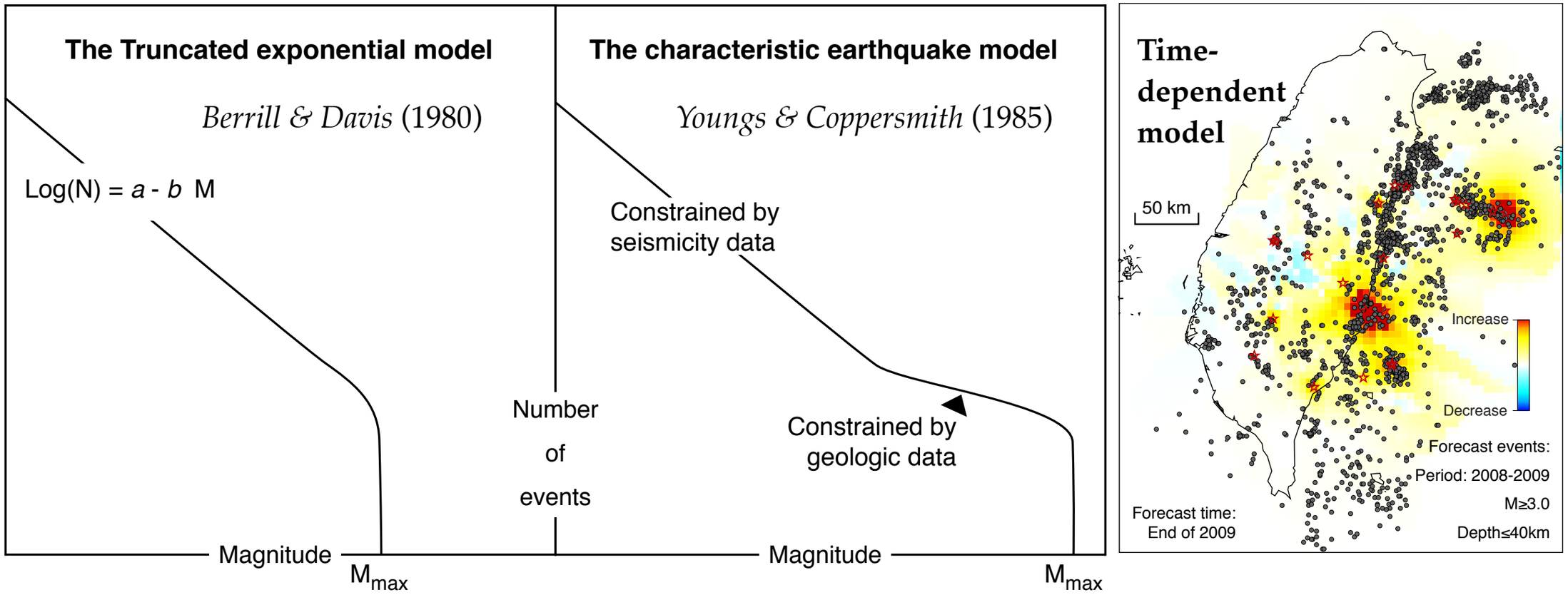
Pick Waveform Duration Time With amplitude >10.0gal & 5%energy<E<95%energy)



8.75 sec

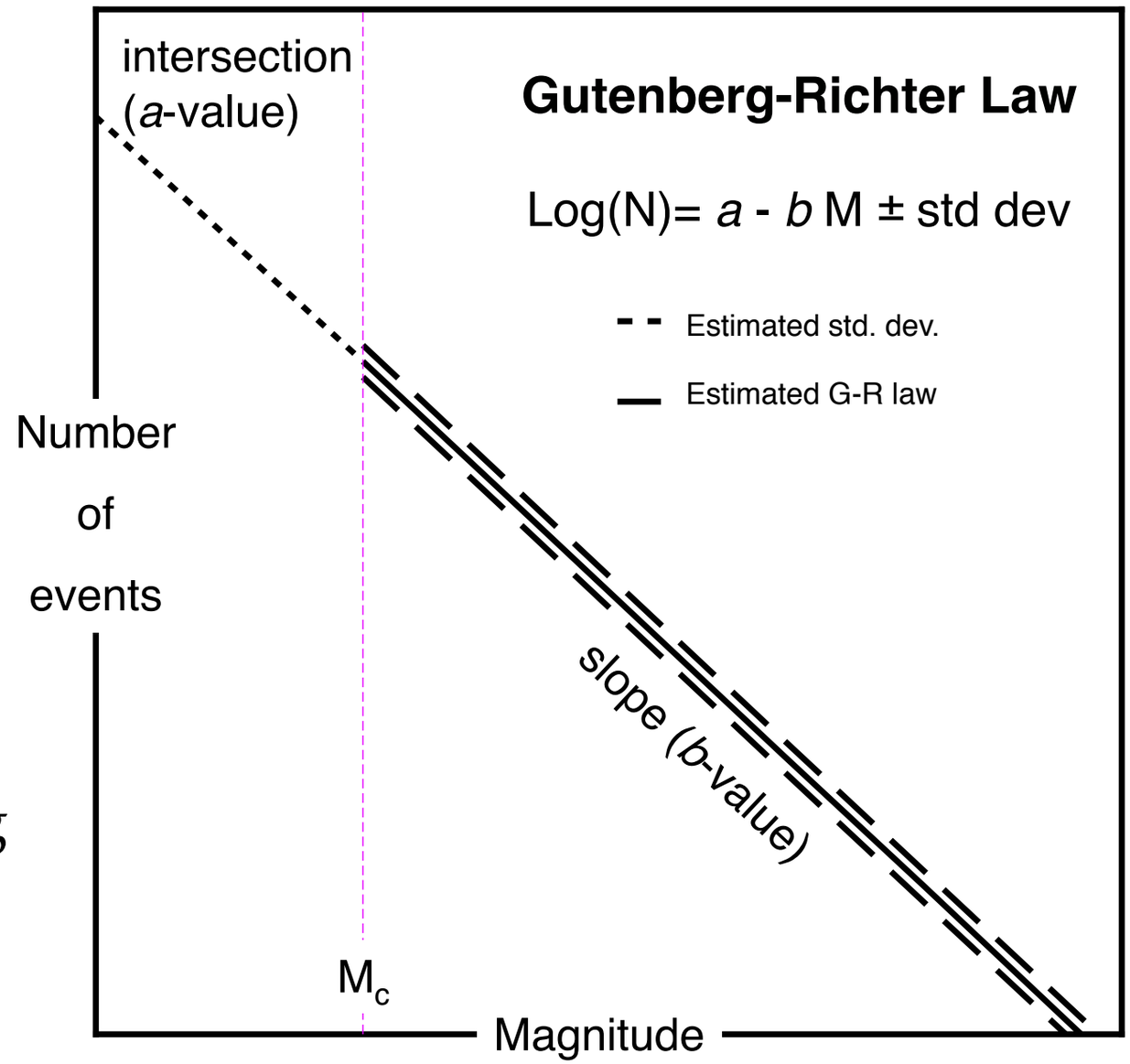
Lee et al. (poster in this Workshop)

The incremental evenly-discretized distribution can be applied for different seismicity rate models



The Truncated exponential model

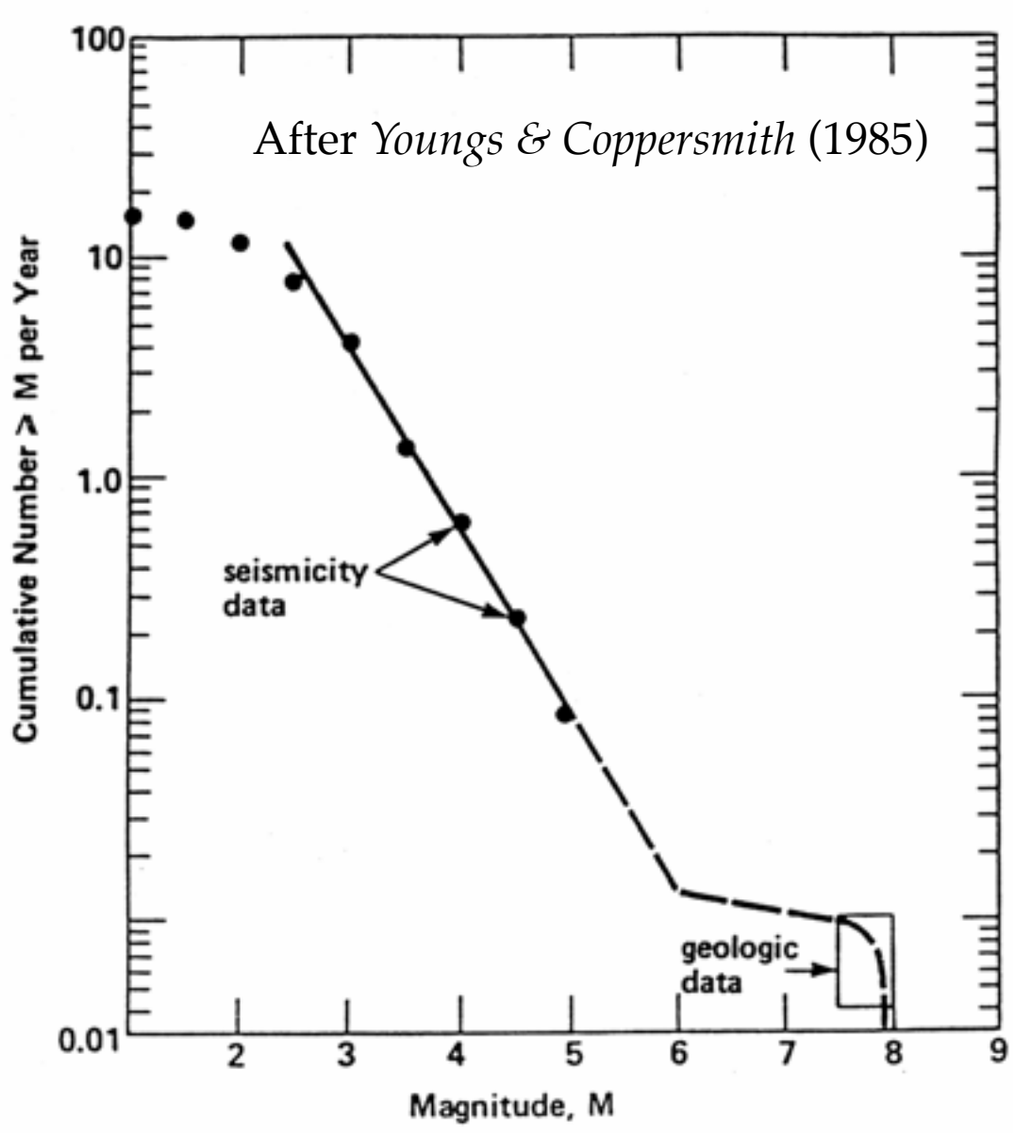
- Cumulative *a*-value
  - according to seismic catalog
- *b*-value
  - according to seismic catalog
- Minimum magnitude
  - according to M_c of seismic catalog
- maximum magnitudes
  - according to scaling law



After *Gutenberg and Richter (1954)*

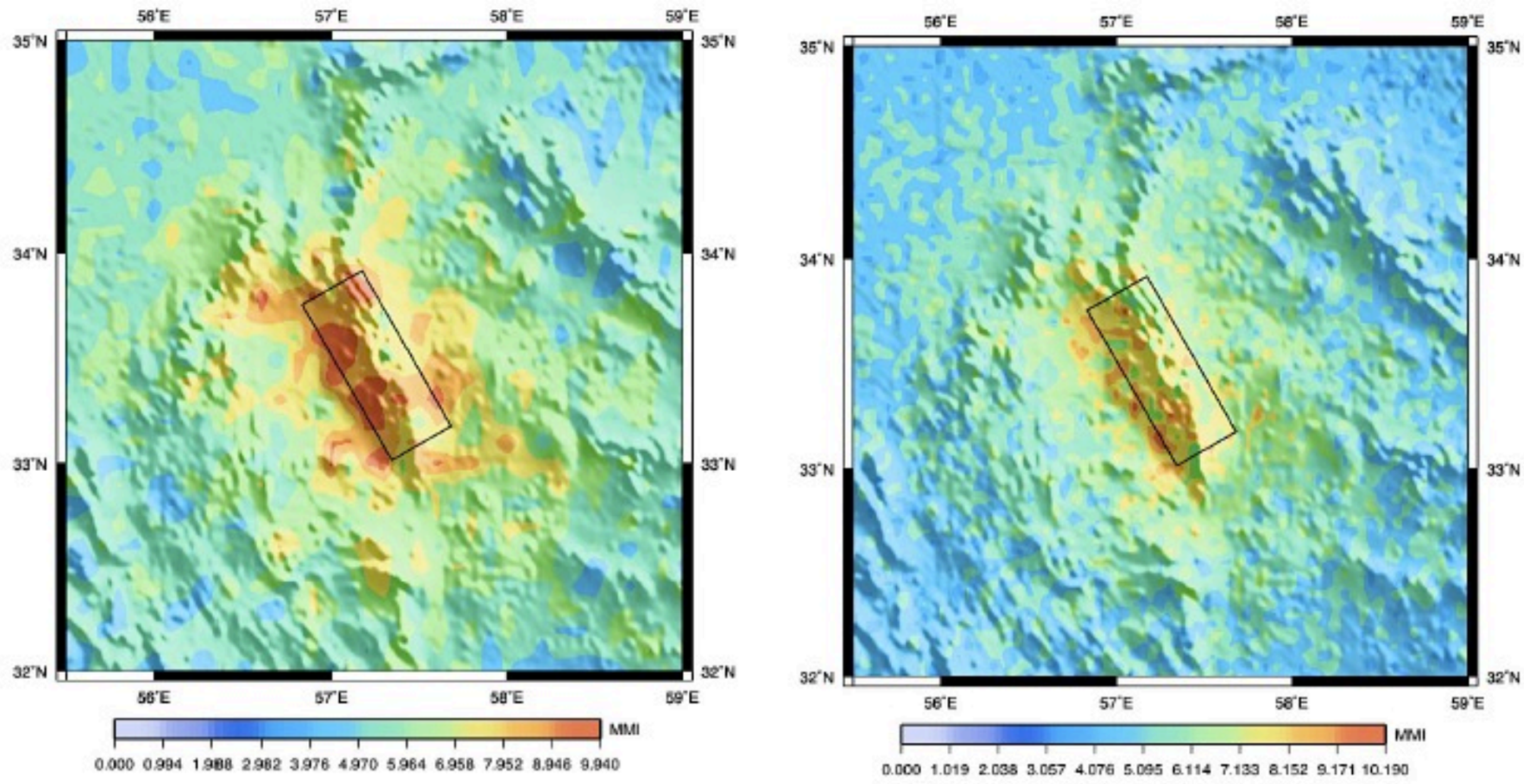
The characteristic earthquake model

- Slip area
    - according to geology or geomophology data
- Slip rate
    - according to geodetic or historical data
- *b*-value
    - according to seismic catalog
- Maximum magnitude
    - according to scaling law



OpenQuake can calculate

Ground motion fields for single events

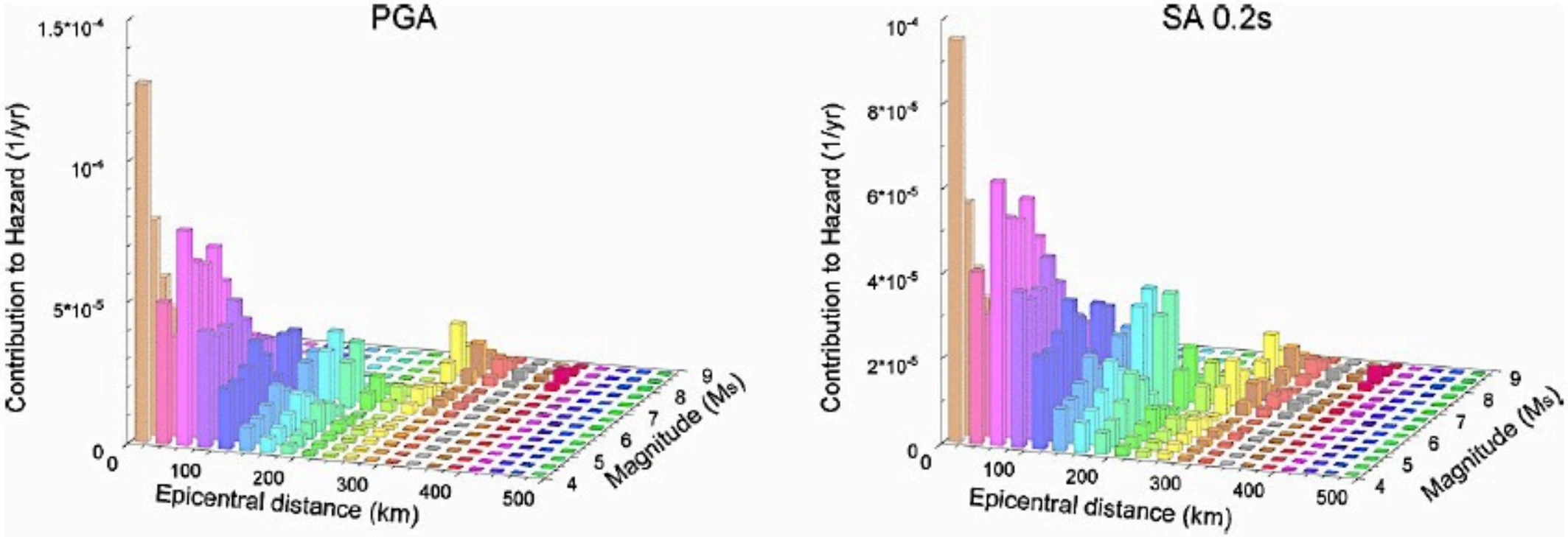


Distribution of the ground motion in a region for a single earthquake

Possible application for the 1906 Meishan earthquake scenario

OpenQuake can calculate

Seismic Hazard disaggregation



Disaggregation provides the contributions to the hazard of discrete combinations of basic parameters considered in the calculations (e.g. magnitude, rupture-site distance)