Site specific probabilistic long-period ground motions evaluated by FDM reciprocity method

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Key points of this study :

1. Site and path uncertainties of Long Period ground motions can be reduced by deterministic simulation by 3D velocity structure model.

2. Probabilistic evaluation of Long Period ground motions due to uncertainty of source require FDM simulation for many heterogeneous source models.

3. For one target site (important structure, see right pictures for examples), reciprocity method greatly reduce computation cost.

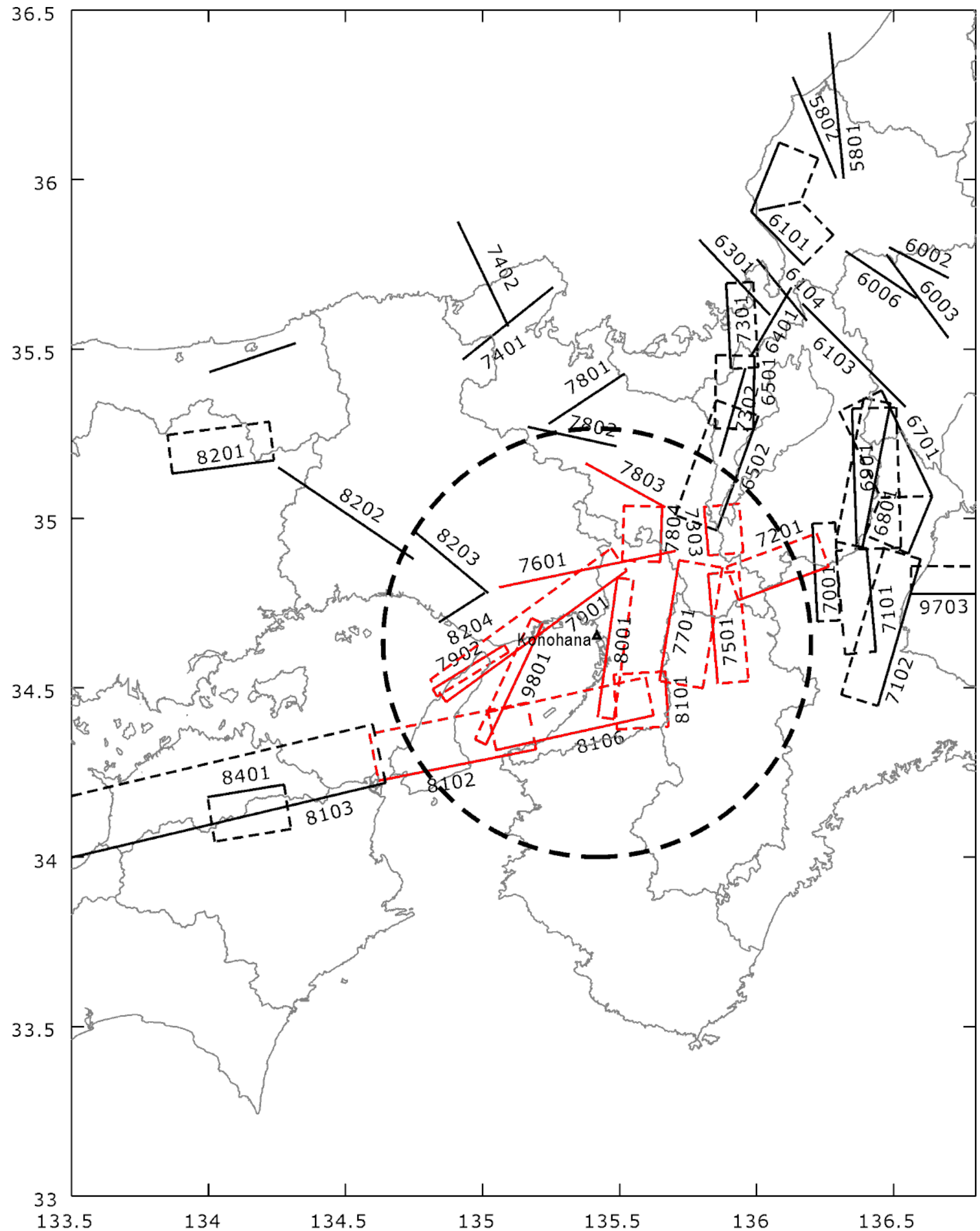
In this work

1. Initial Source model: characterized source models (NIED, 2009, Irikura recipe).
2. Uncertainties: hierarchical heterogeneous source model with random SMGA location (Sekiguchi and Yoshimi, 2010).
3. Plus: 3 cases of rupture start to account for directivity variations.
4. 3D crust and basin velocity structure (JIVSM, Iwaki and Iwata, 2011).
5. FDM Reciprocity method for waveform simulation (Petukhin et al., 2017).
6. Validation of simulated SA values by GMPE (Uchiyama and Midorikawa, 2004).
7. PSHA by the Probabilistic Seismic Hazard Maps methodology of NIED (NIED, 2009).
8. Result: seismic hazard curves for site Konohana (OSKH02).

Source models for this study:

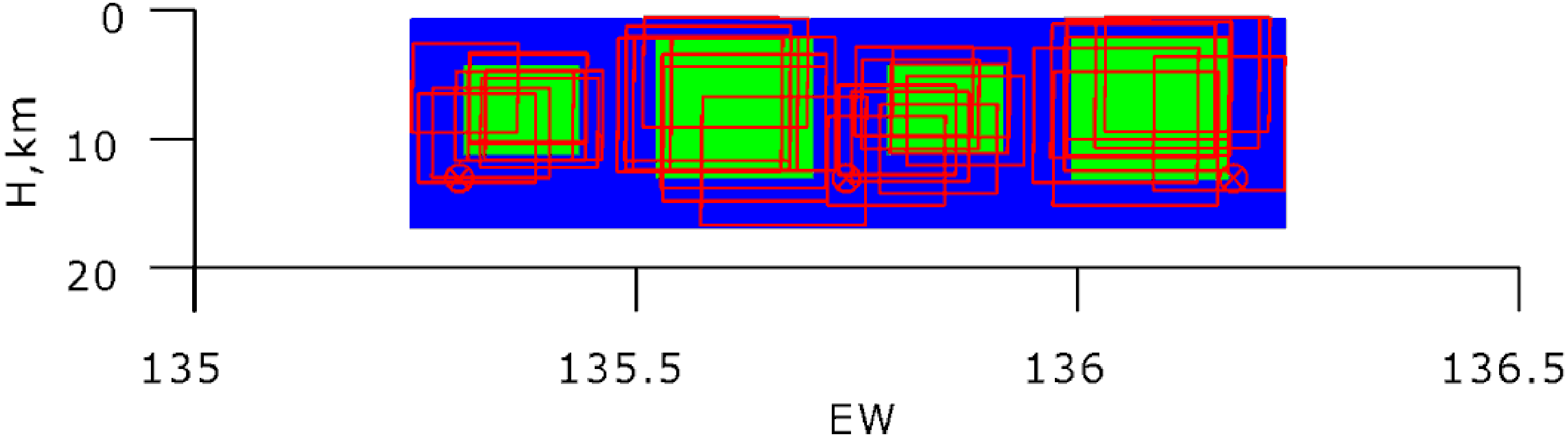
Major active seismic faults

- Black: specified major active faults (NIED, 2009)
- Red: faults used for this study (14 faults within 70km from target site Konohana)



* **Technical Reports on National Seismic Hazard Maps for Japan.** Technical Note of the National Research Institute for Earth Science and Disaster Prevention **No.336**.

Source models for this study:
Example for fault 7901 (Rokko/Awaji)

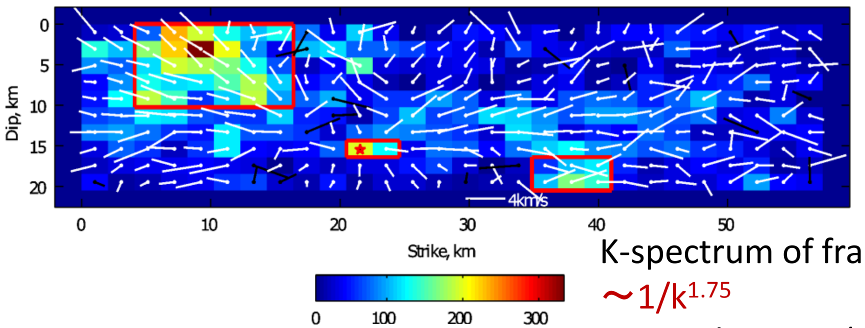


Green area - initial SMGAs,
Blue area – background,
Red rectangles – randomly shifted SMGAs,
Red point - rupture starting points.

14 characterized faults
10 random SMGA locations
3 rupture starting points
5 heterogeneous cases
Total: 2100 source models
(150 models for 1 fault)

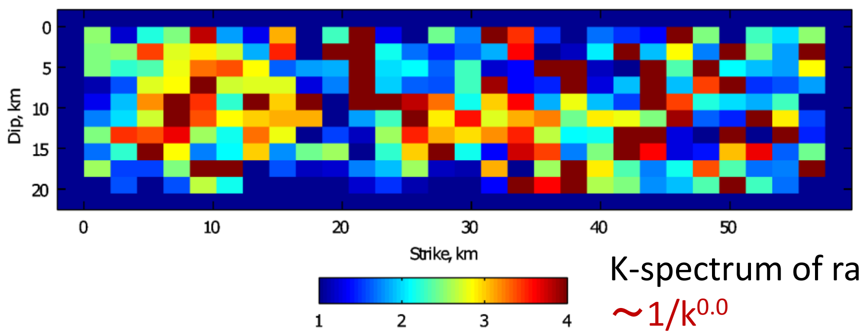
Construction of multi-scale heterogeneous source model

Example of source inversion result
(Kobe 1995, by Sekiguchi et.al. , 2000):



Slip, cm

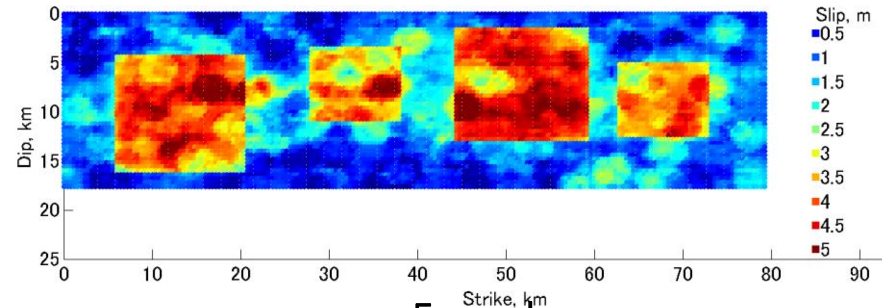
K-spectrum of fractal type
$\sim 1/k^{1.75}$
Mai and Beroza (2002)



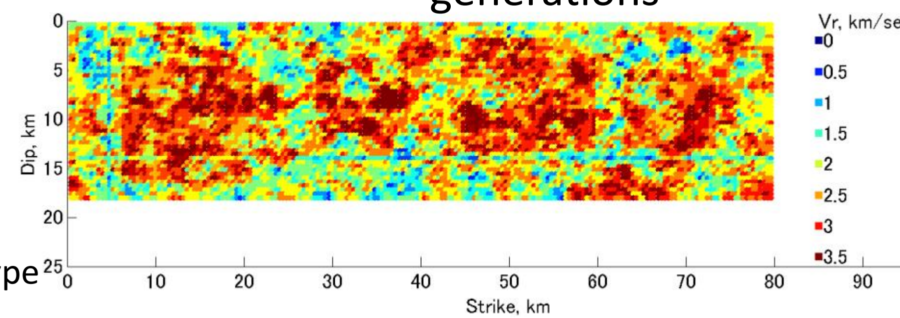
Vr, km/s

K-spectrum of random type
$\sim 1/k^{0.0}$
Petukhin and Miyakoshi (2016)

Model for fault 7901
(Rokko/Awaji):



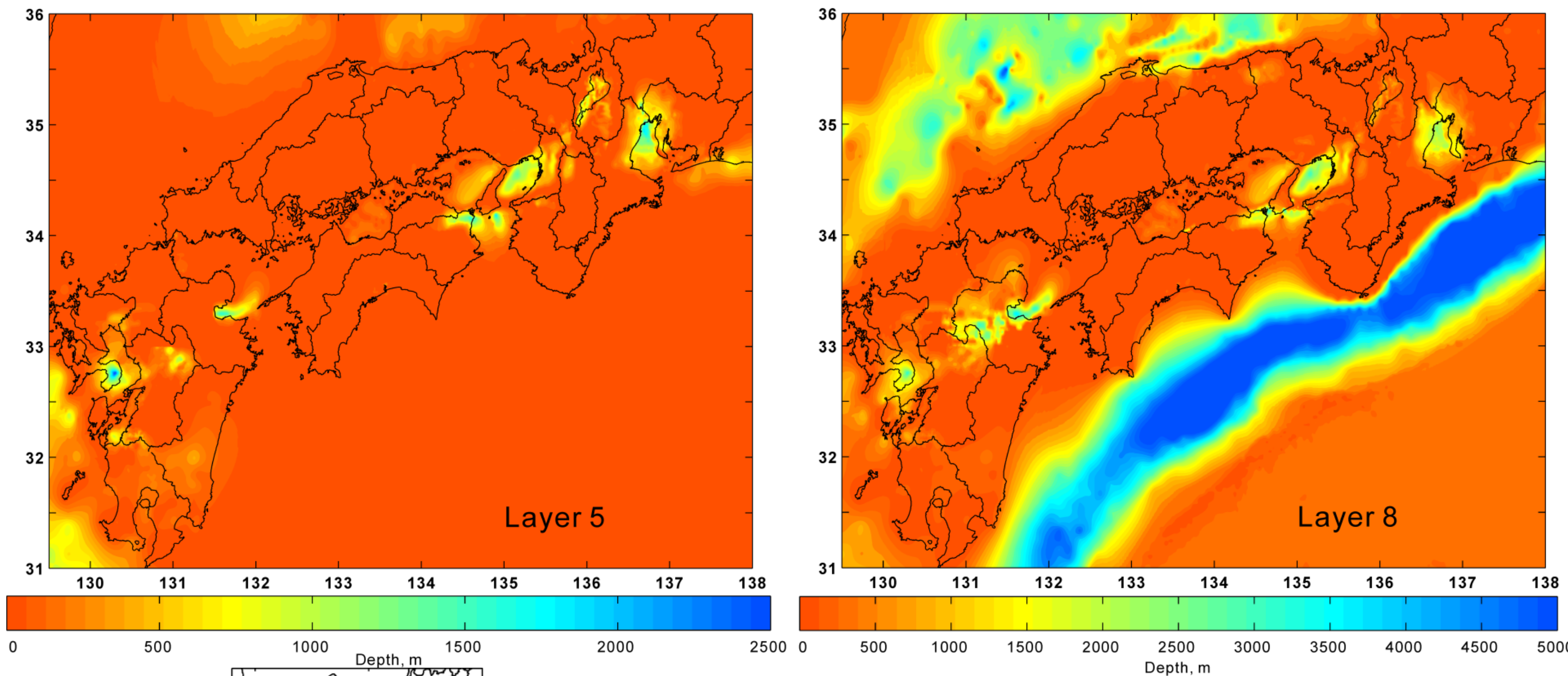
5 random
generations

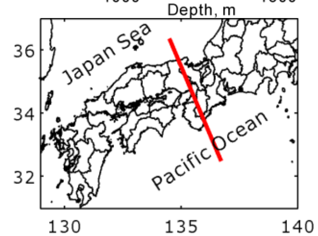


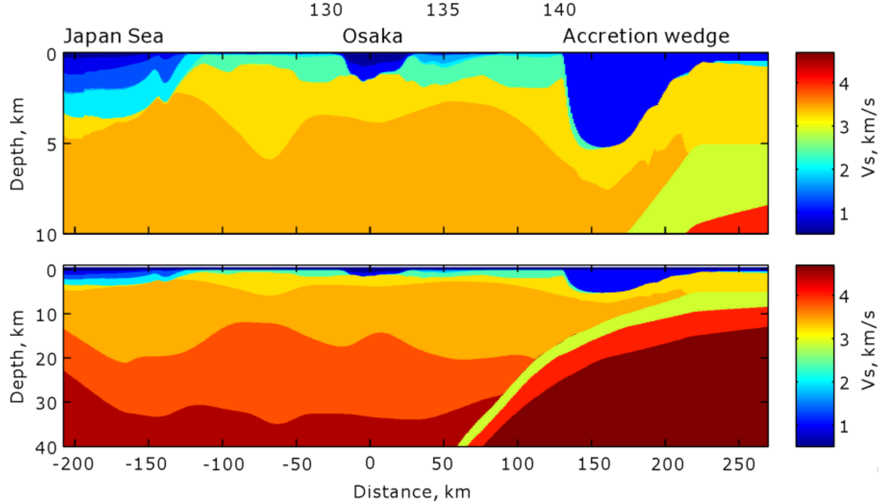
*SMGA areas are first scale of slip heterogeneities. Patches of a smaller scales are generated randomly.

*Up to 13000 point sub-sources in the source models

For details see e.g. Sekiguchi and Yoshimi (2010)





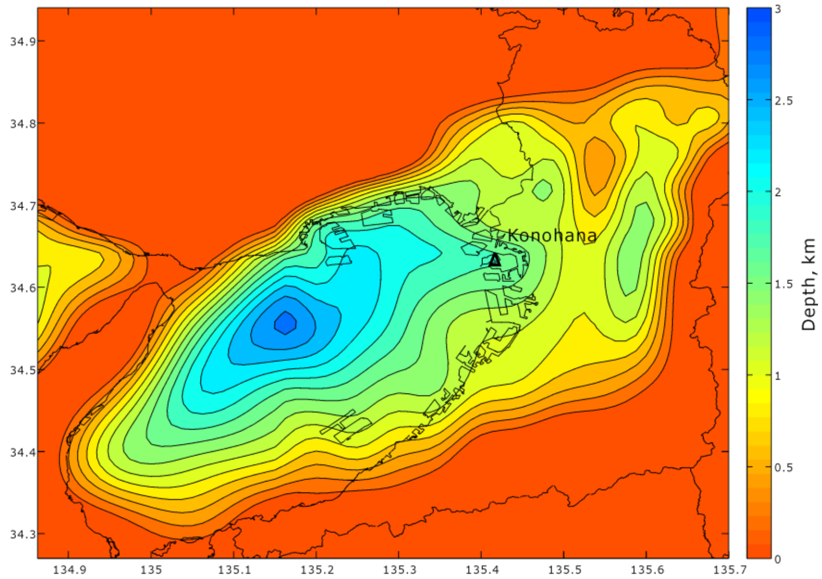


Japan Integrated Velocity Structure Model (JIVSM)

Model consists of 23 velocity layers, waveform tuned, include crust and subduction plate structures, and ready to use for long-period simulations.

Osaka basin model

Depth of basement of sediments in Osaka basin:

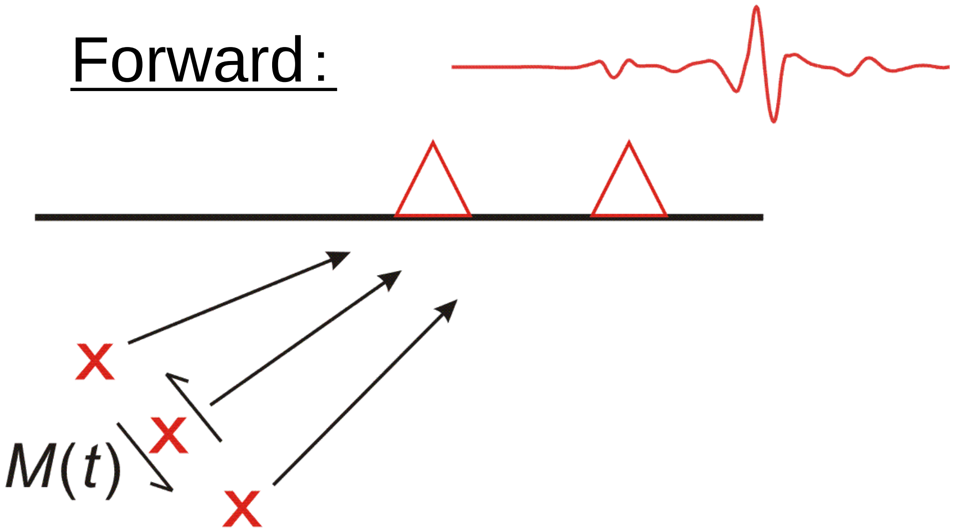


Osaka basin structure: 3 layer spline model of Iwaki and Iwata (2011), embedded into JIVSM model.

Important model feature: tuning of model using linear waveform inversion, target periods 3-10sec.

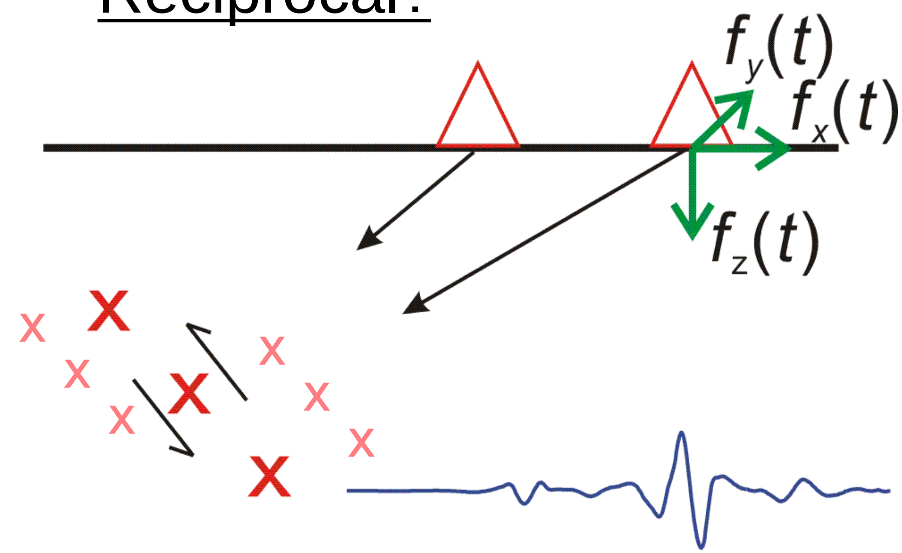
Calculation of waveforms by Reciprocity method

Forward:



*Need many runs of FDM for every source model separately

Reciprocal:



*For each site and any number of sources need just 3 runs of FDM

Advantages of reciprocity method:

- In case of large number of source models and a small number of target sites – strongly reduce calculation time.
- Many parameter settings（strike, dip, rake, source time function）can be made on a fast waveform manipulation step, after finishing slow FDM step.

Don’t need to re-run FDM for different strike, dip, rake, Trise, …!

Reciprocal approach for extended source

Step 1. Calculate and store GFs for all subsources; dummy STF T_{rise_d} .

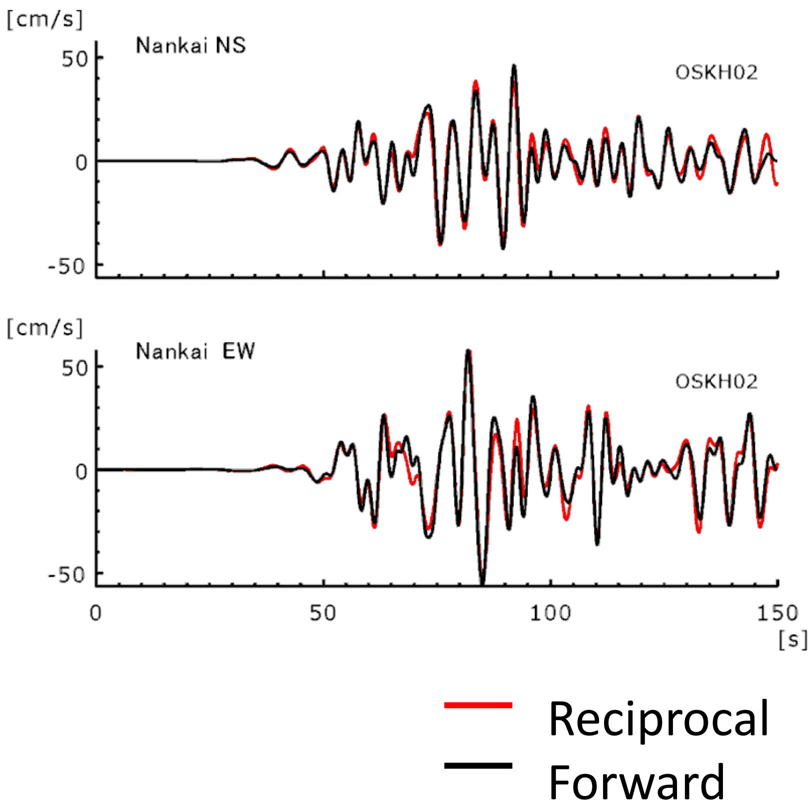
Step 2. Calculate GFs for target values T_{rise}; source time function Nakamura and Miyatake(2000):

$$GF_i(f) = GF_d(f) \cdot \frac{STF(f \mid T_{rise\_i})}{STF(f \mid T_{rise\_d})}$$

Step 3. Make summation of pre-calculated GFs:

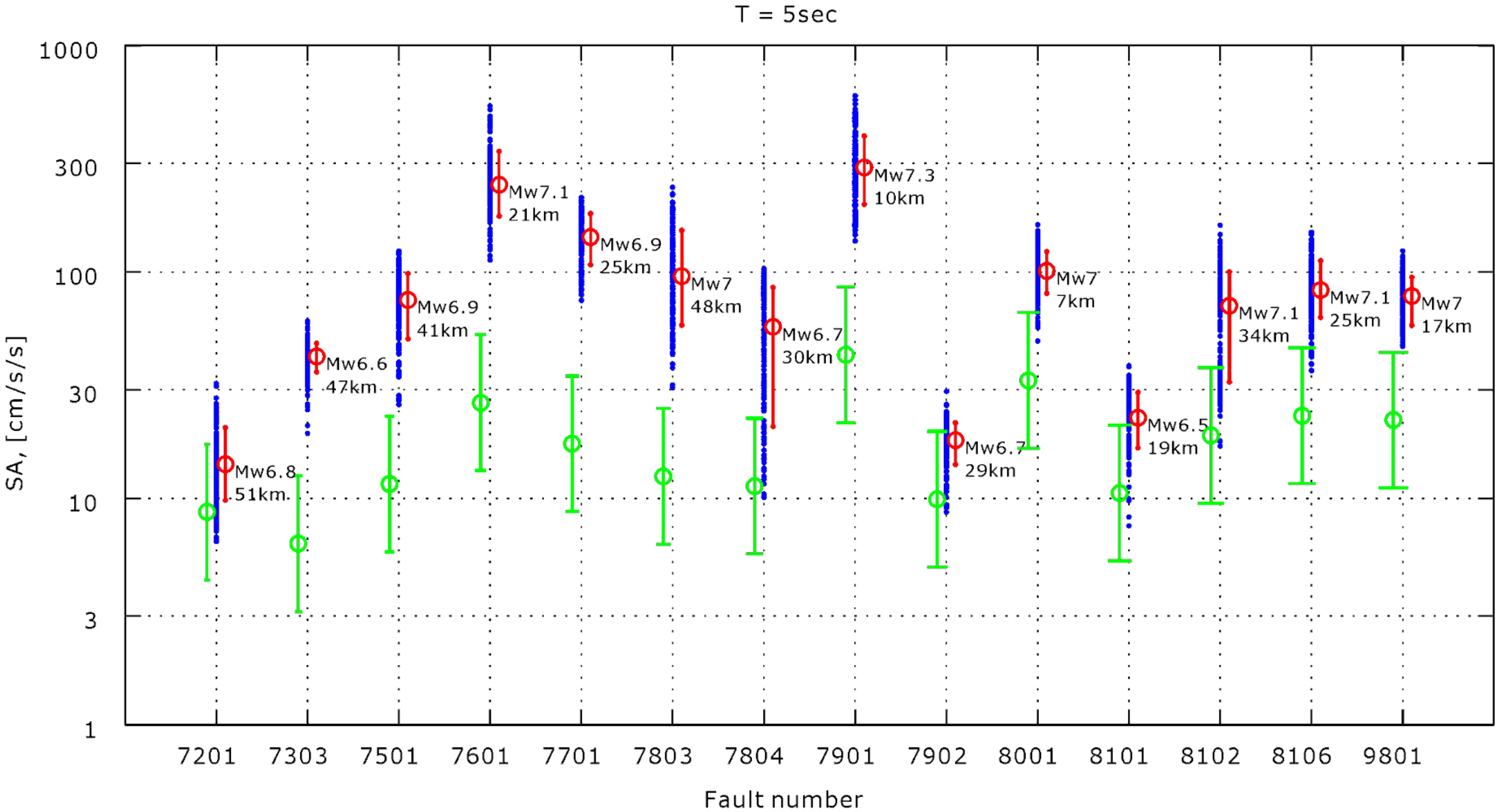
$$V(t) = \sum_{i=1}^{N} GF_i(t - t_{r\_i}) \cdot \frac{M_{0\_i}}{M_{0\_d}} ,$$

Example of calculated waveforms



*Petukhin et al., 2017

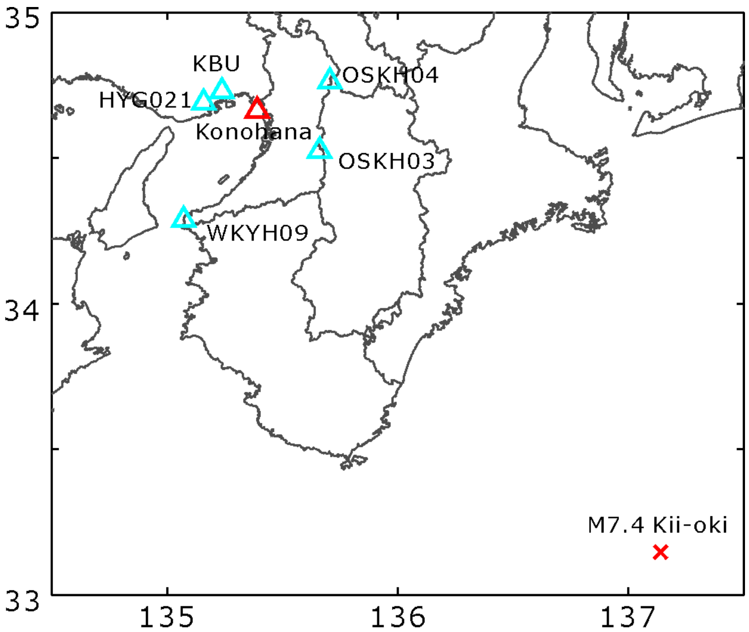
Simulation results and comparison to GMPE for SA(T=5sec, rock)



Blue points – SA simulation results, red – median+/-std,
green – Uchiyama and Midorikawa, 2004, <u>for Vs30 = 500m/s</u>.

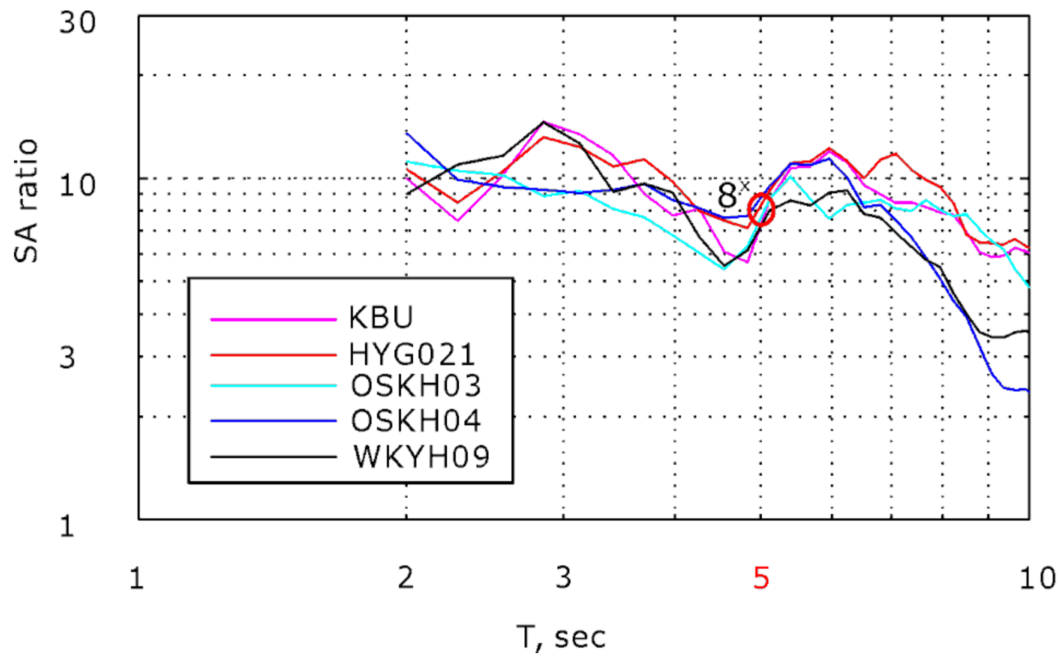
Spectral ratio site correction for Konohana (OSKH02) relative to sites with Vs30 ≈ 500m/s

Target earthquake and sites:



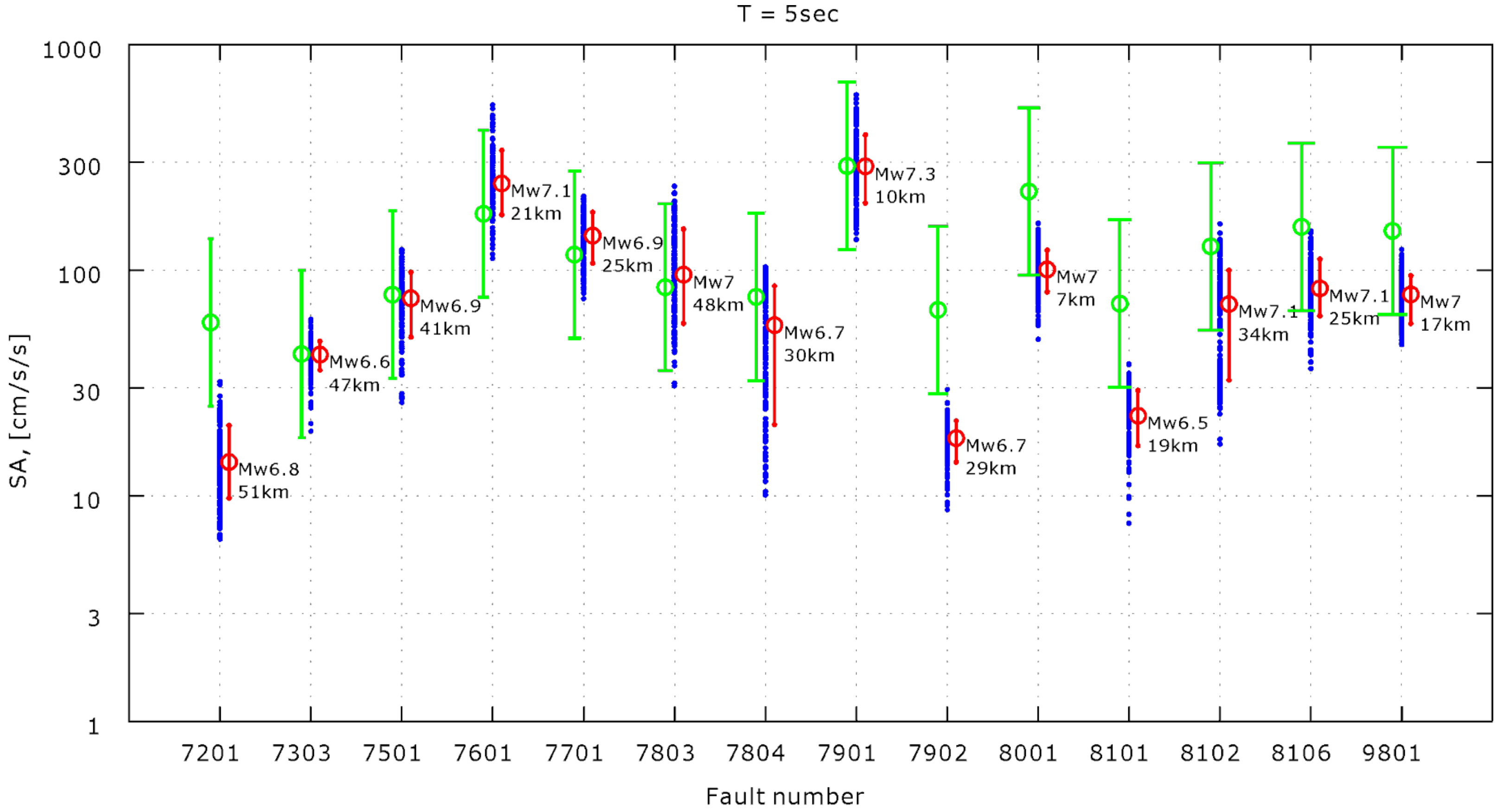
Red: target site Konohana
Blue: sites with Vs30 = 500m/s

Spectral ratios:



SA ratio of blue sites to target site at T = 5 sec equals 8.0 in average.
This value is assumed as the site correction.

Simulation results and comparison to GMPE & spectral site correction



Blue points – simulation results, red – median+/-sigma,

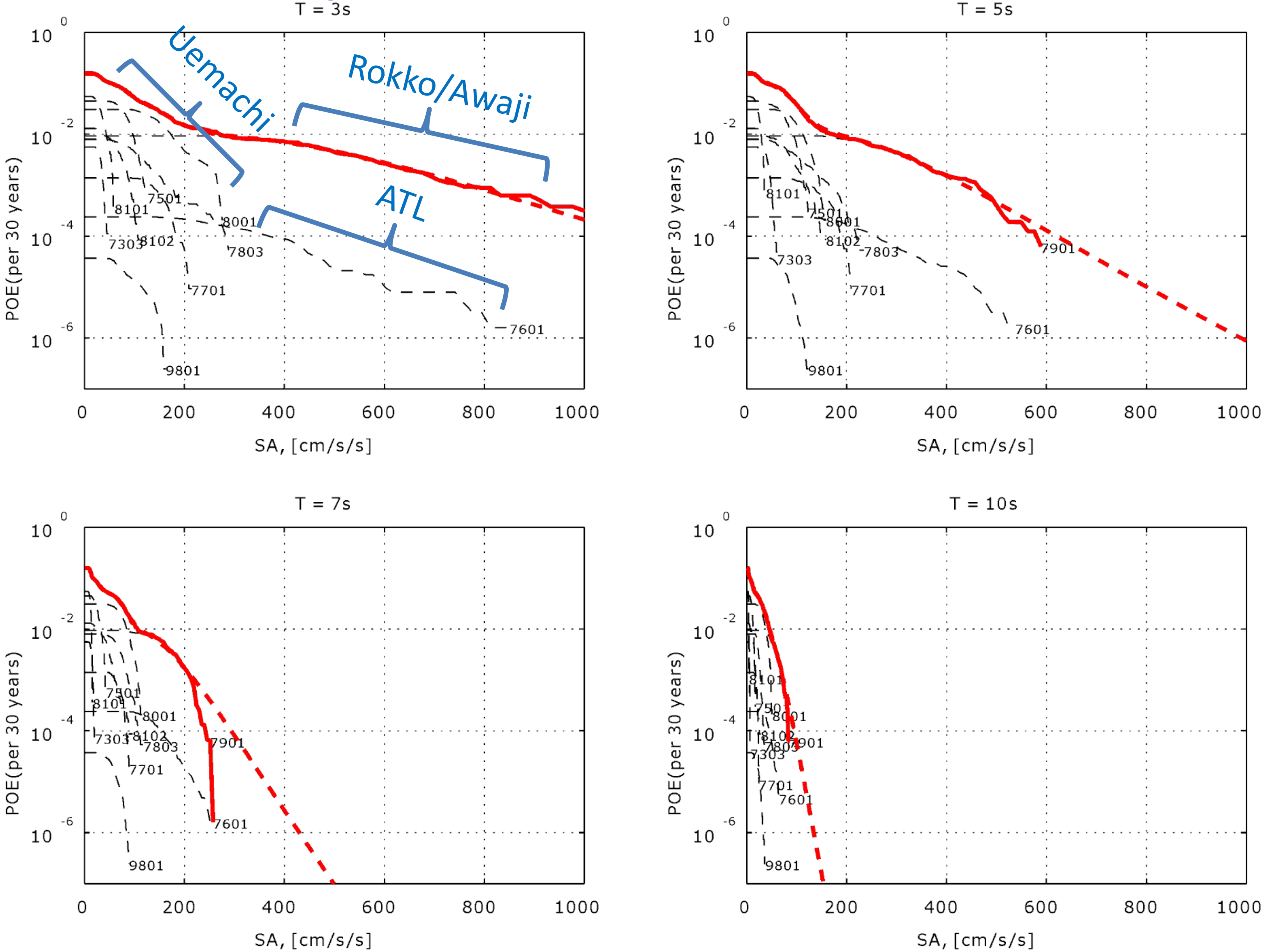
green – Uchiyama and Midorikawa, 2004, with <u>spectral ratio site correction</u>.

Occurrence probability of earthquakes in target major active fault zones

Fault zone	Mjma	Prob(30 yr), %
7201	7.3	0
7303	7.4	0.0013-0.56
7501	7.4	3.1-4.5
7601	7.7	0-0.024
7701	7.5	0-0.14
7803	7.6	0.017-0.8
7804	7.6	nan
7901	7.9	0-0.94
7902	7.1	0
8001	7.5	2.9-3.1
8101	6.9	0-5.5
8102	7.7	0.15-1.3
8106	7.7	nan
9801	7.5	0-0.0037

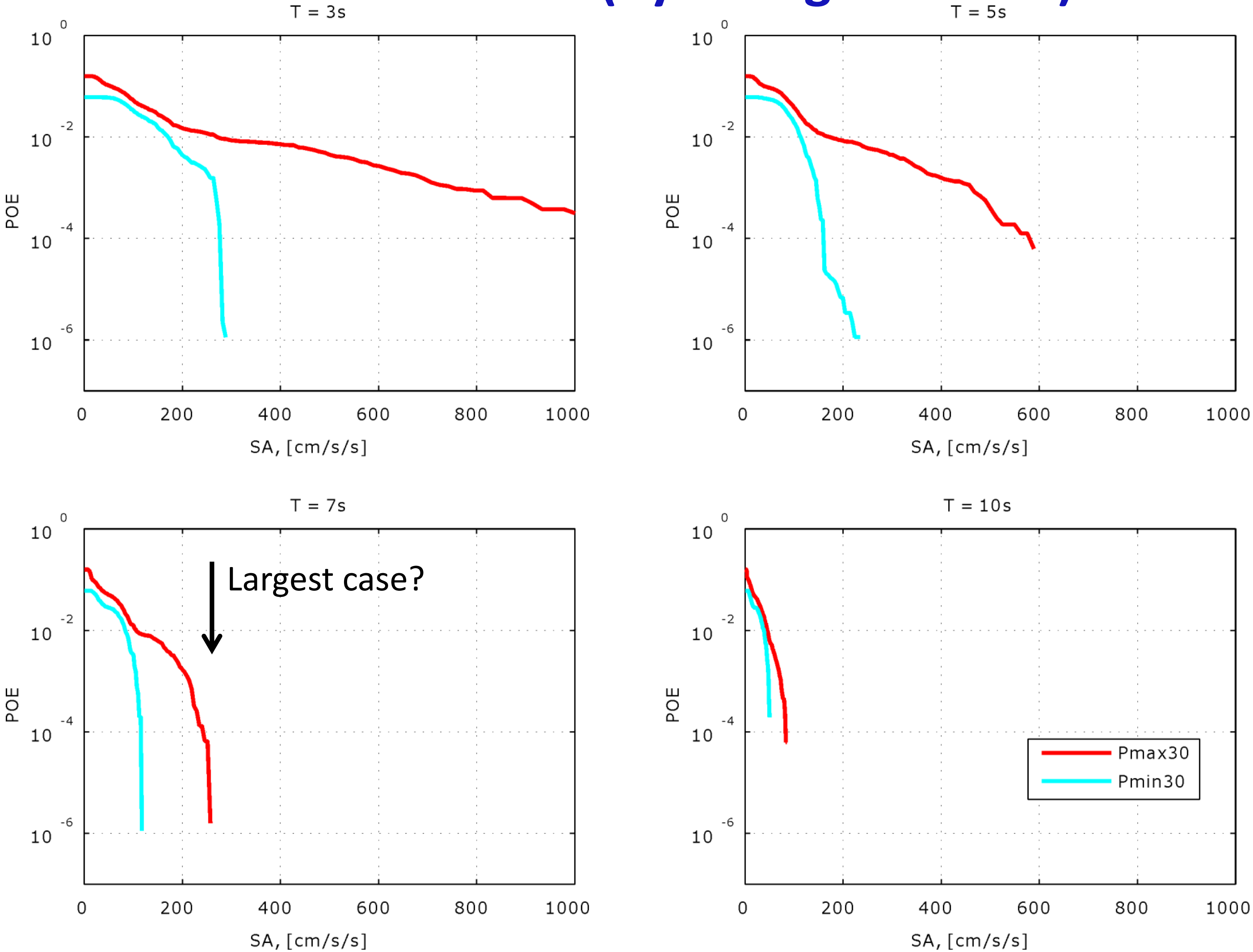
*from NIED, 2009

Example of the hazard curve estimation

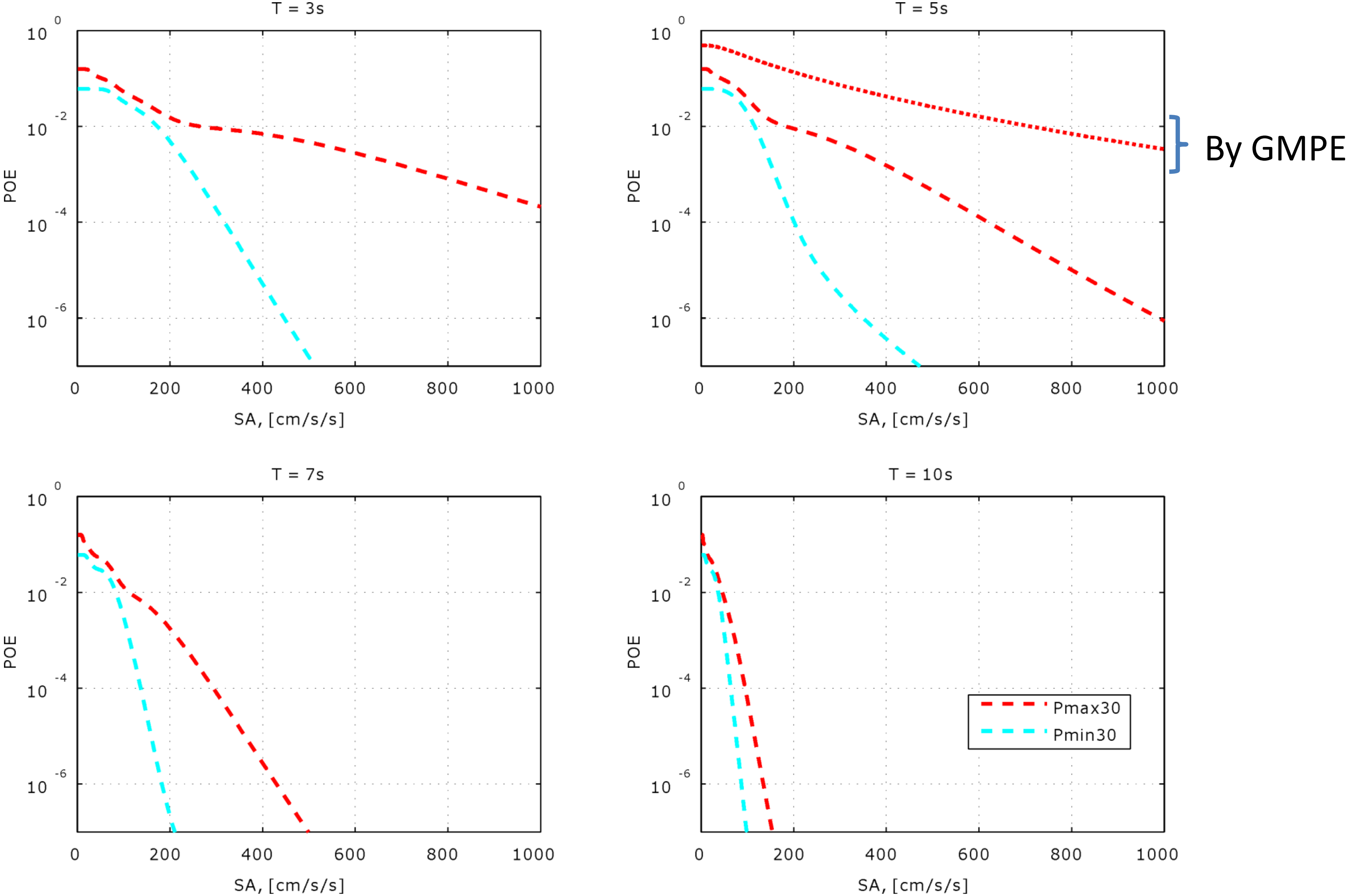


By histogram By log-normal fitting

Hazard curves (by histogram itself)



Hazard curves (by log-norm fitting of histogram)



Conclusions

1. **We applied PSHA approach to the case of long-period ground motions at one target site. Source models are characterized source models (NIED, 2009, Irikura recipe) with random SMGA location combined to the hierarchical heterogeneous source model (Sekiguchi and Yoshimi, 2010).**

2. **For validation, we calculated SA values using GMPE for response spectra of Japanese eqs. (Uchiyama and Midorikawa, 2004) and compared to simulated SA values at Konohana site.**

3. **Considering 30yr and 50yr probabilities of earthquake occurance (NIED, 2009) we calculated hazard curves at Konohana site.**

References

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