International Conference on Earthquake Engineering

CISMID: 40 Years of Science, Innovation and Infrastructure Assessment for Resilient Cities

AI-Powered Approach for Evaluating Site Amplifications using Microtremor H/V Spectral Ratios

Prof. Hiroyuki Miura
(Hiroshima University, Japan)

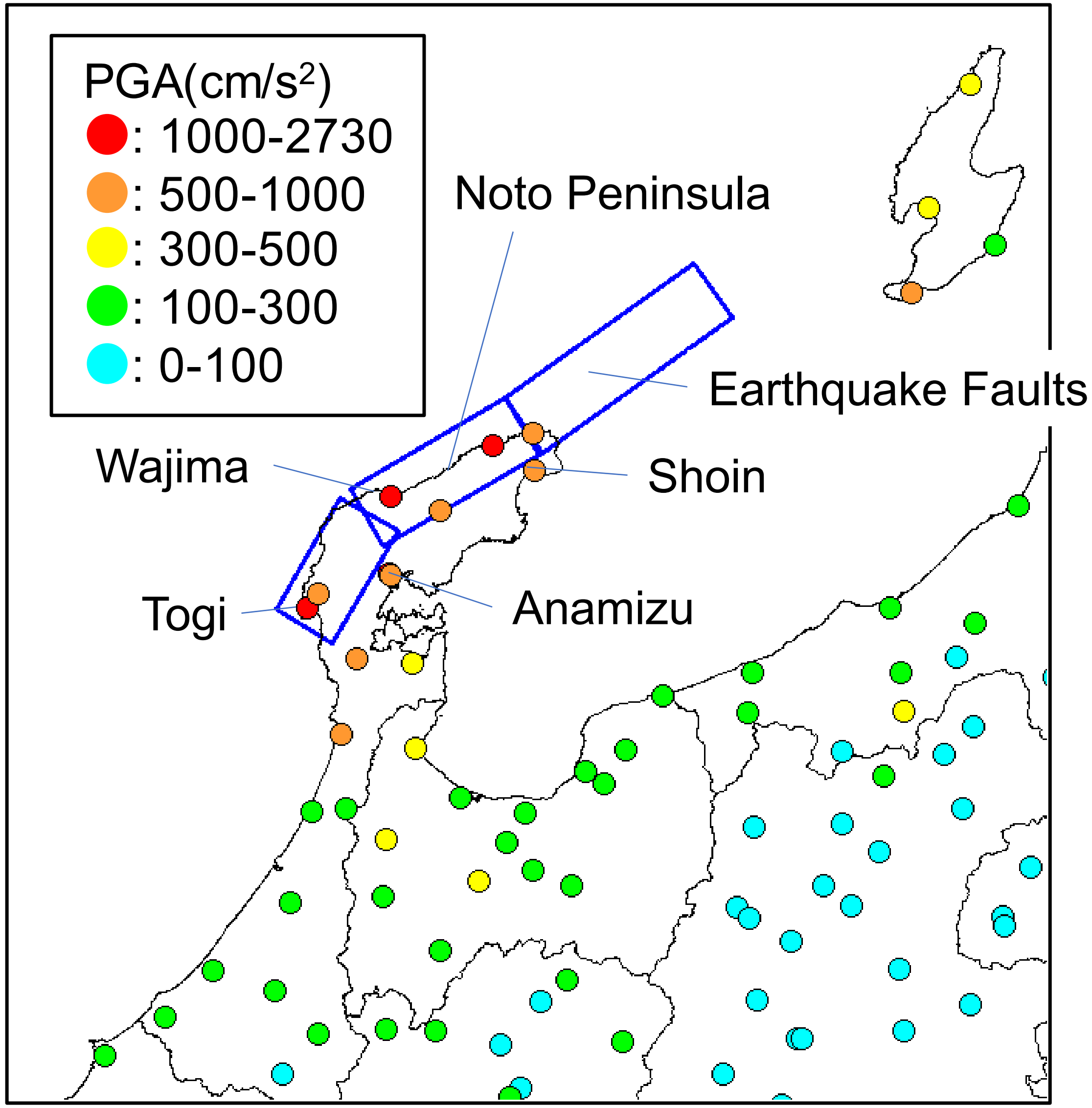
Contents

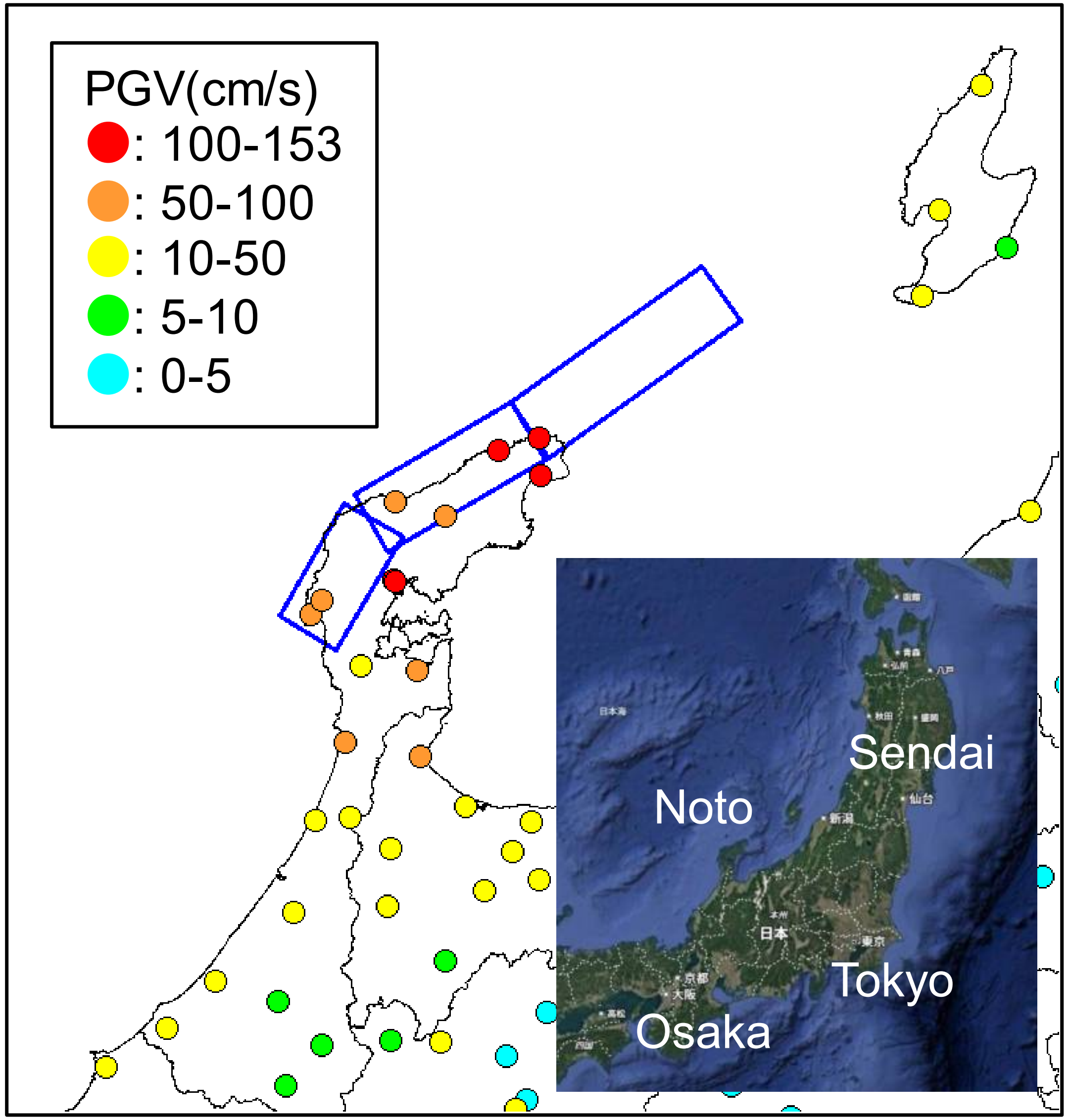
- Lessons learned from the 2024 Noto earthquake in Japan
- Applications of Microtremor H/V Spectral Ratio (MHVR) for evaluation of site amplifications
- AI-based approach for estimating response spectra using MHVR and an existing ground motion model.

Ground Shaking and Building Damage (Video) during the 2024 Noto Earthquake

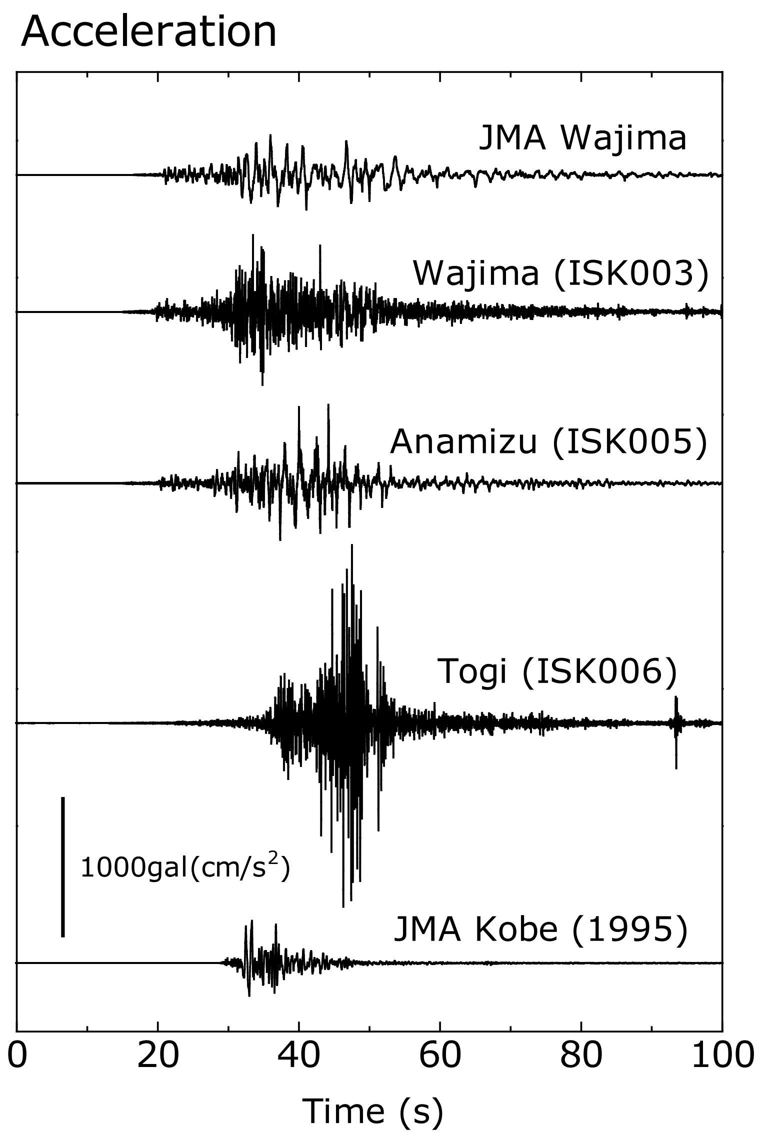
https://www.youtube.com/watch?v=xAA7RI7paCA&list=PLZgTYVtJ9ro7pSxAj9JBf-d4bvR-PIQZb&index=7

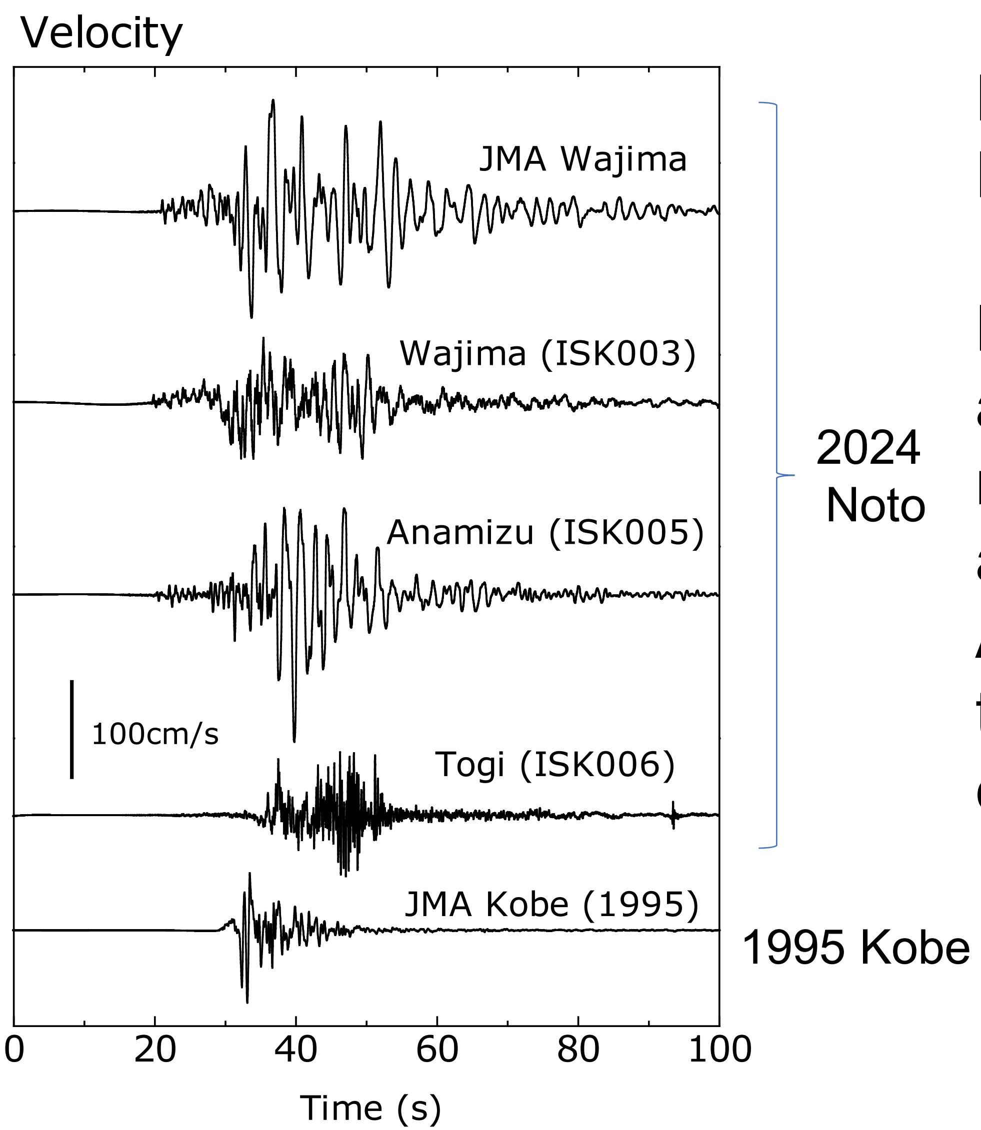
Distribution of PGAs and PGVs in the 2024 Noto EQ.





Observed Strong Motions in the 2024 Noto EQ

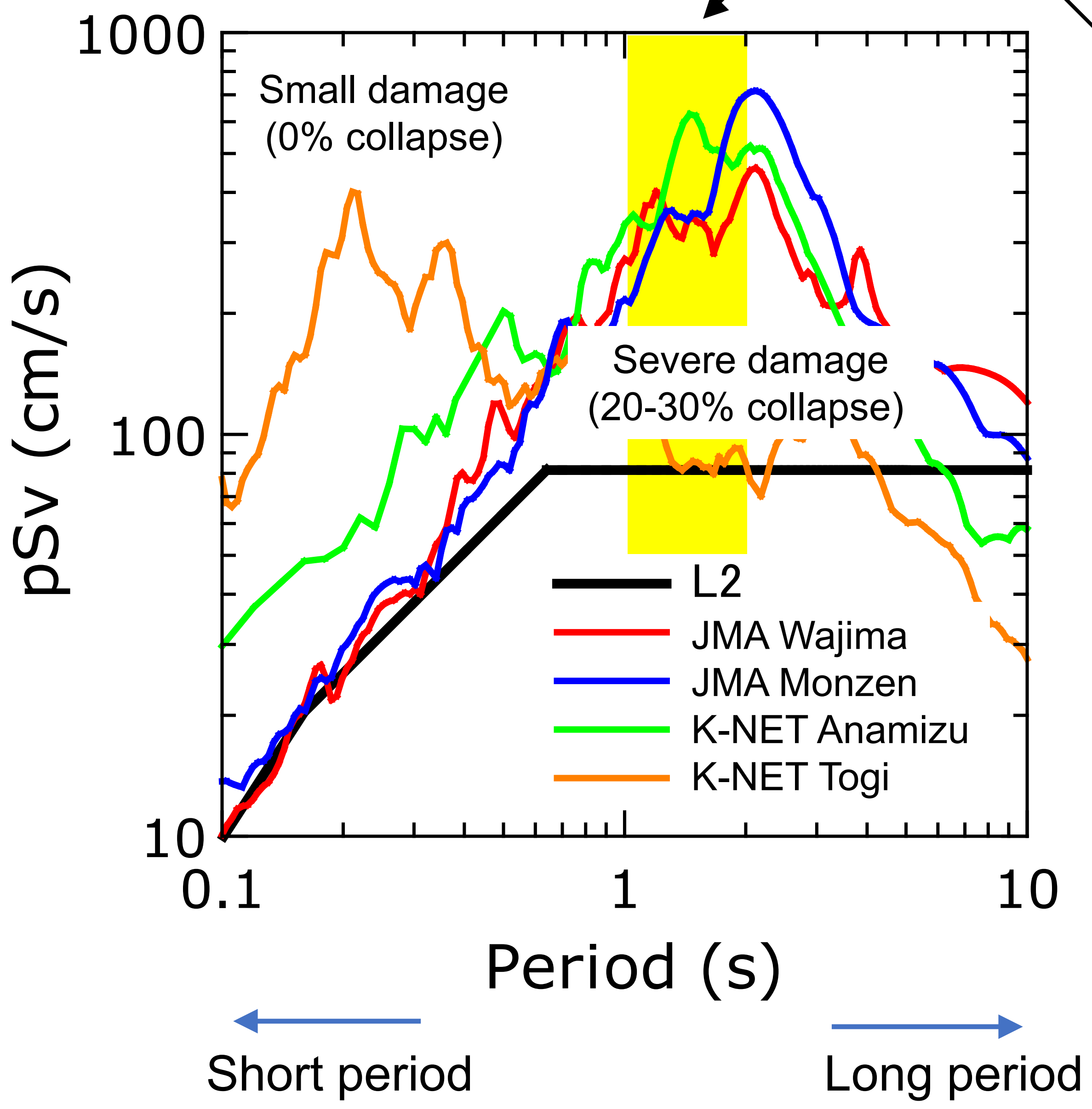




PGA>1g (980cm/s^2)
PGV>150 cm/s

Much larger acceleration and velocity were recorded in the damaged areas (Wajima and Anamizu) than those in the 1995 Kobe earthquake.

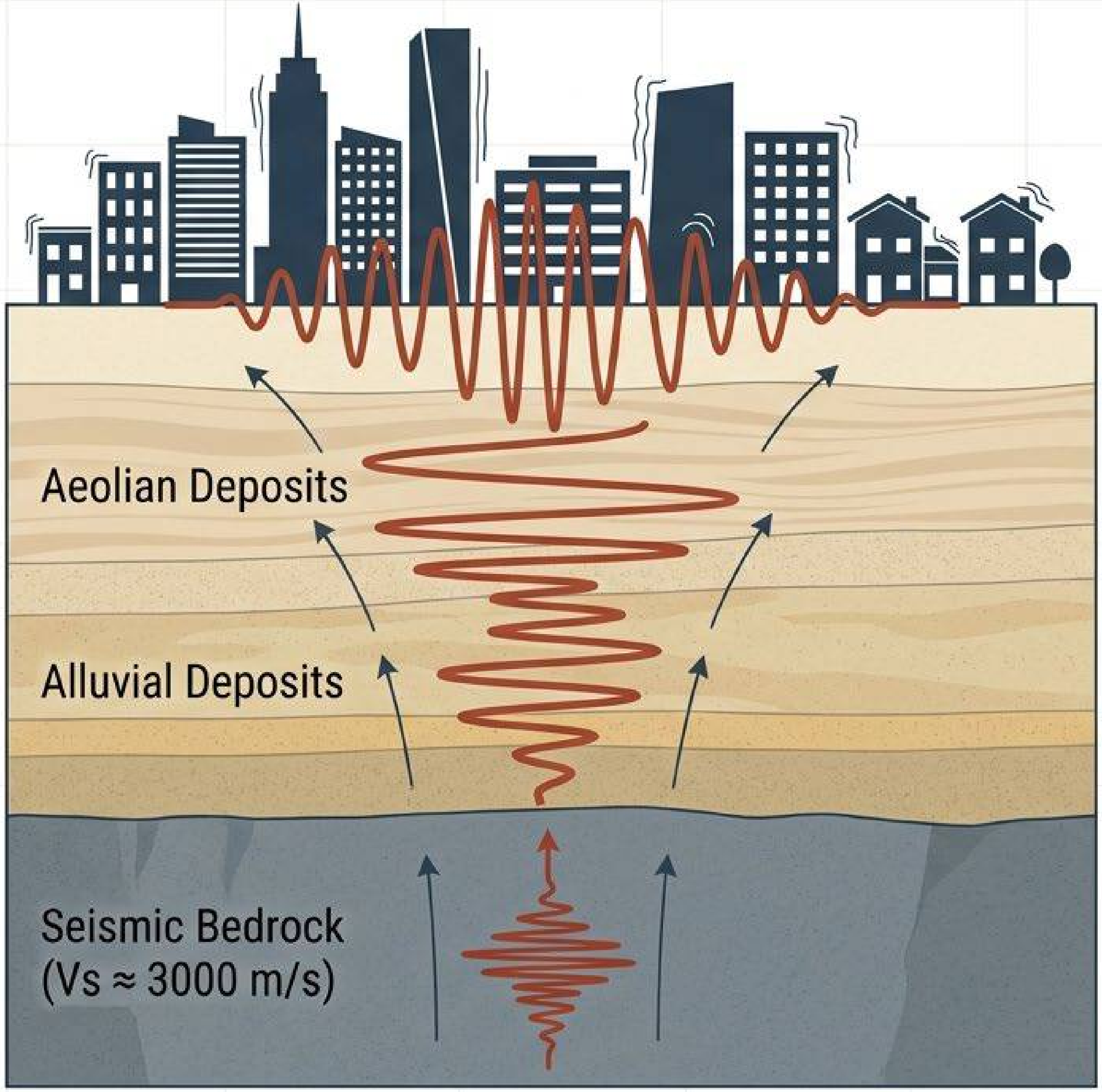
Characteristics of Response Spectra



Period 1-2 second:
Most dangerous period zone to Japanese timber houses

Seismic intensity 7 (maximum intensity in Japanese scale) was recorded in Monzen, Anamizu and Togi. However, building damage in Togi was much smaller than other areas due to the difference of spectral intensity.

It means that prediction of **spectral characteristics** is very important for accurate strong motion prediction and building damage estimation.



The Site Effect Imperative

Surface ground motions are a product of source, path, and site effects. Accurately mapping Site Amplification Factors (SAF) is critical for structural safety, yet gathering deep S-wave velocity profiles for every urban site is physically and financially prohibitive.

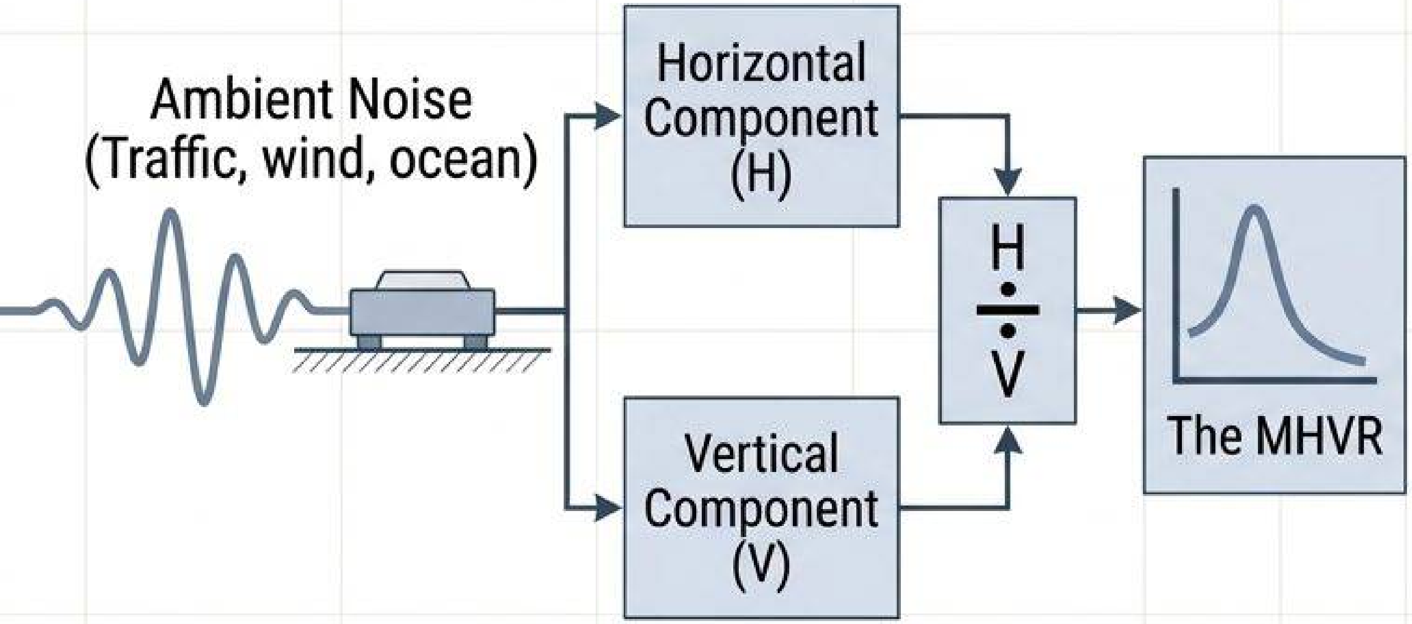
Methods for Evaluating Site Effects

	S-Wave Velocity Logging (Boreholes)	Earthquake Records (Spectral Inversion)	Microtremor H/V Ratio (MHVR)
Cost / Effort	Extremely High	High (requires long-term observation)	Near-Zero (20 minutes of ambient noise)
Spatial Coverage	Point-specific	Limited to active stations	Ubiquitous (anywhere, anytime)
Frequency Accuracy	High	High	High (perfectly matches SAF peaks)
Amplitude Accuracy	High	High	Low (severely underestimates true amplification)

The Bottleneck: MHVR is the most scalable method, but its raw amplitude cannot be directly used for engineering.

Microtremor H/V Ratio

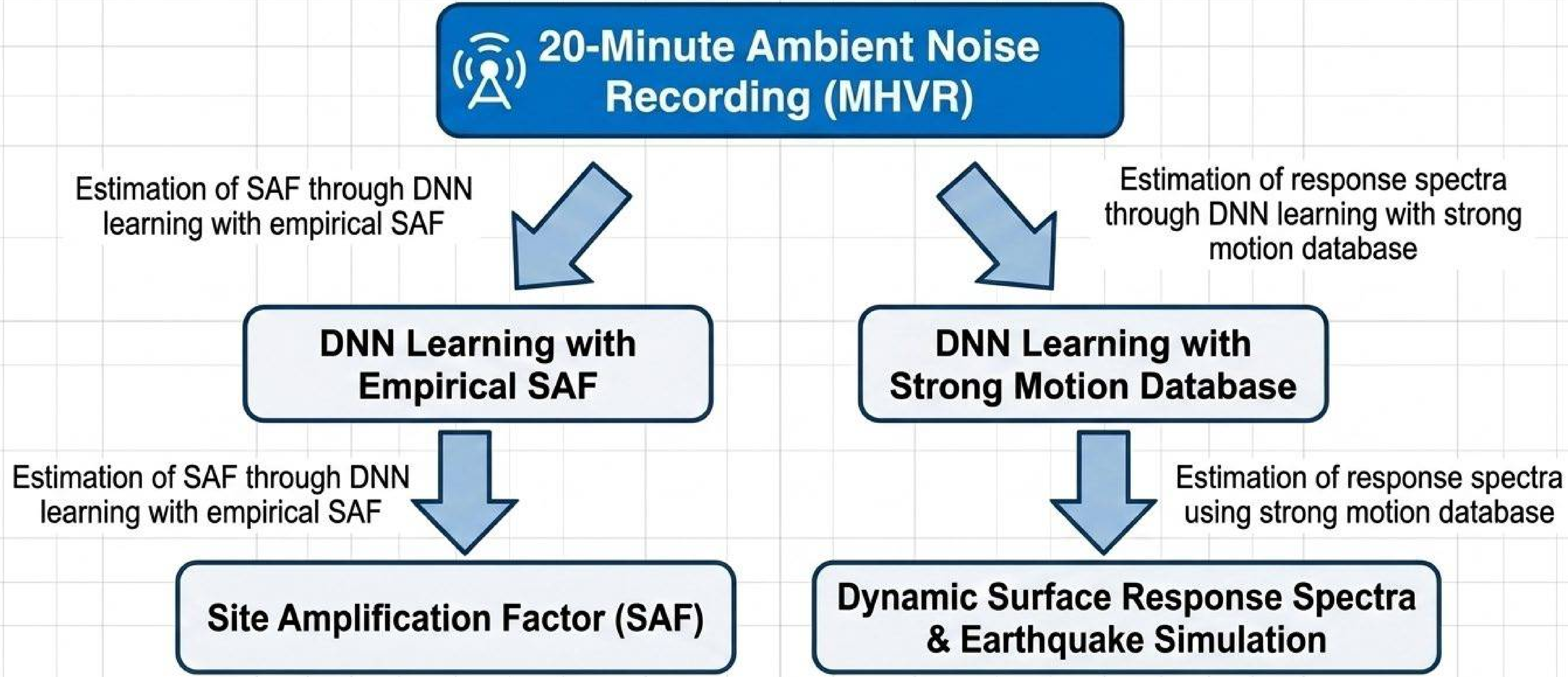
MHVR



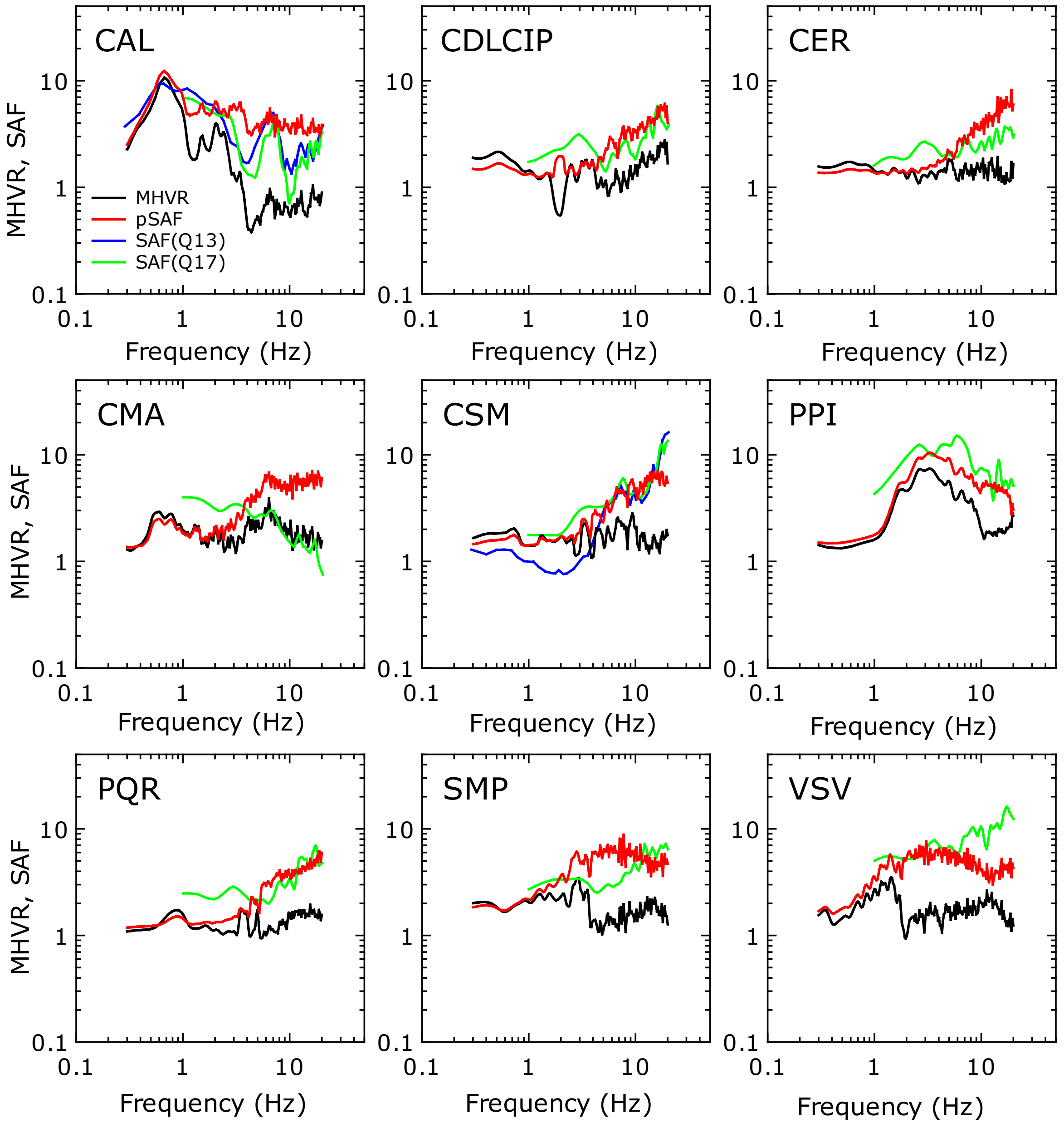
- **1989 (Nakamura):** Proposed MHVR as a proxy for dynamic subsurface characteristics.
- **2011-2018 (Diffuse Field Concept):** Theoretical grounding via Kawase and Sánchez-Sesma. Proves MHVR maps to the S-wave velocity structure.
- **2019 (Double Empirical Correction):** Kawase proposes correcting MHVR to SAF via Earthquake H/V Ratios, establishing a mathematical bridge.

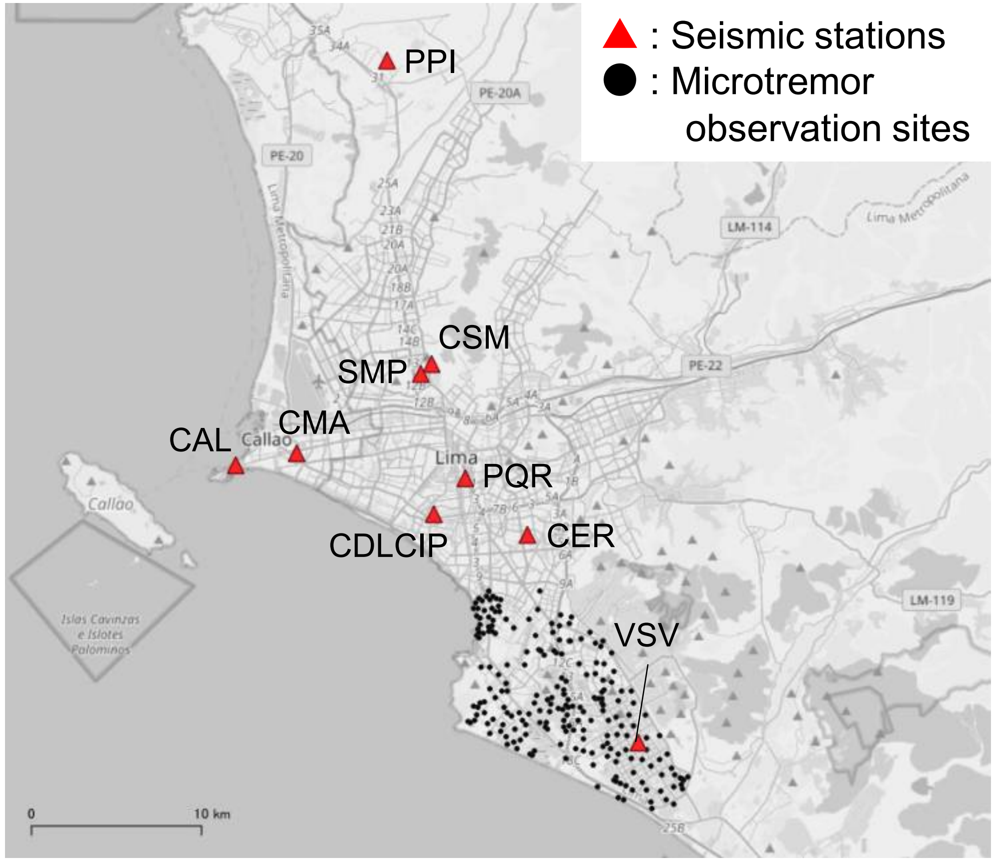
The consensus: MHVR spectral shapes mirror actual site amplifications, but a transform function is required to bridge the mathematical gap.

Unlocking Geological & Dynamic Applications from Ambient Noise



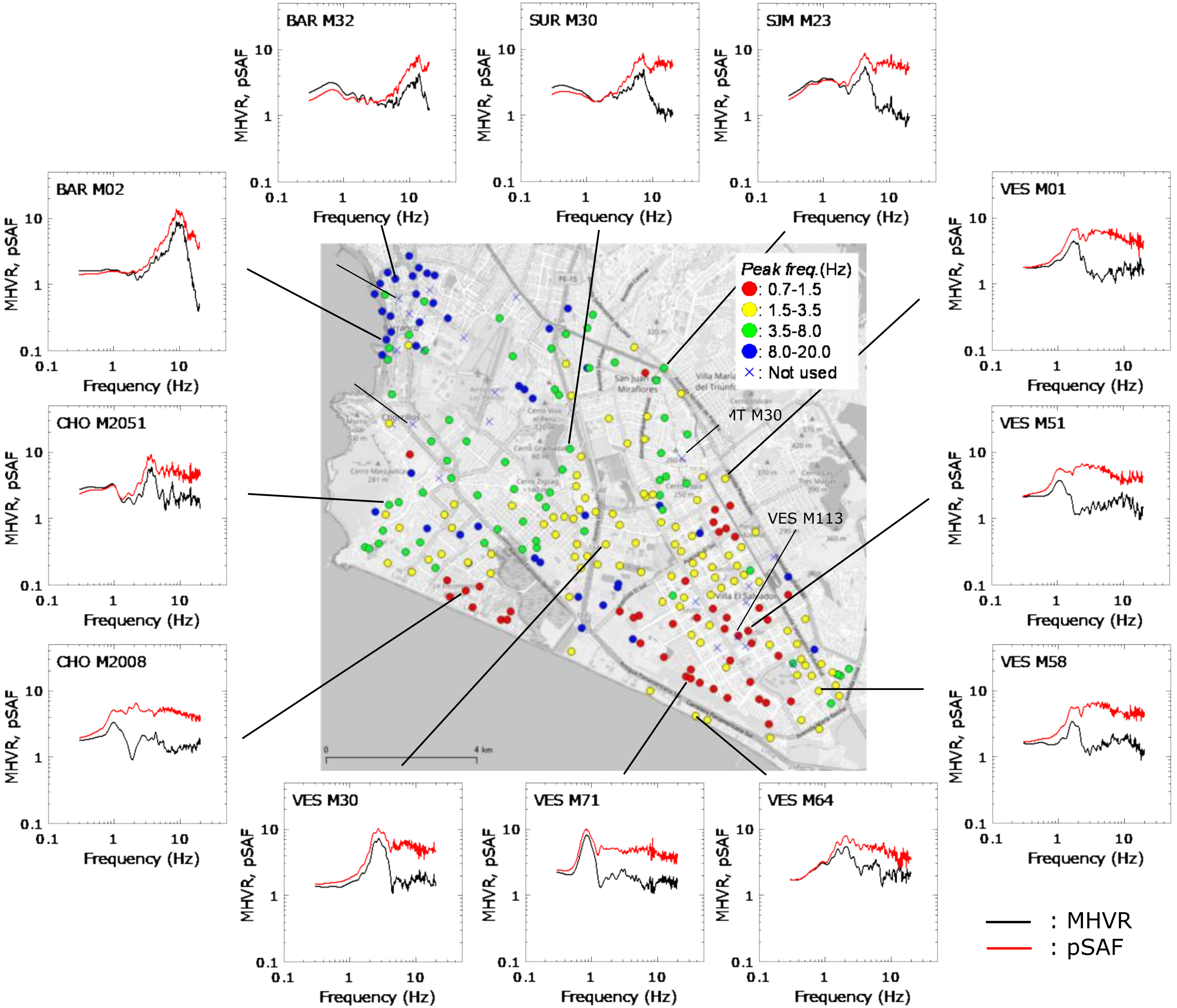
Estimation of SAF from MHVR at Lima, Peru





SAFs at seismic observation stations were derived from observed seismic motions.

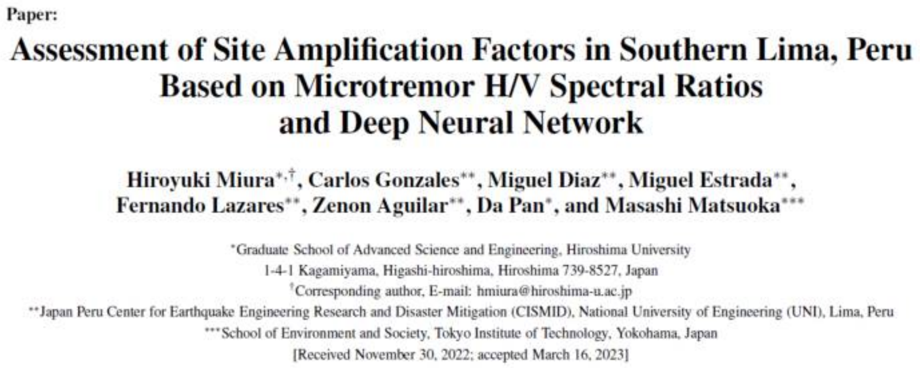
Estimation of SAFs at Chorrillos and Villa El Salvador in Lima



pSAFs (pseudo Site Amplification factors) were estimated by densely observed microtremor data in Lima.

Reference: Miura et al. (2023) *Journal of Disaster Research*, 18(4)

https://doi.org/10.20965/jdr.2023.p0298



Paper:

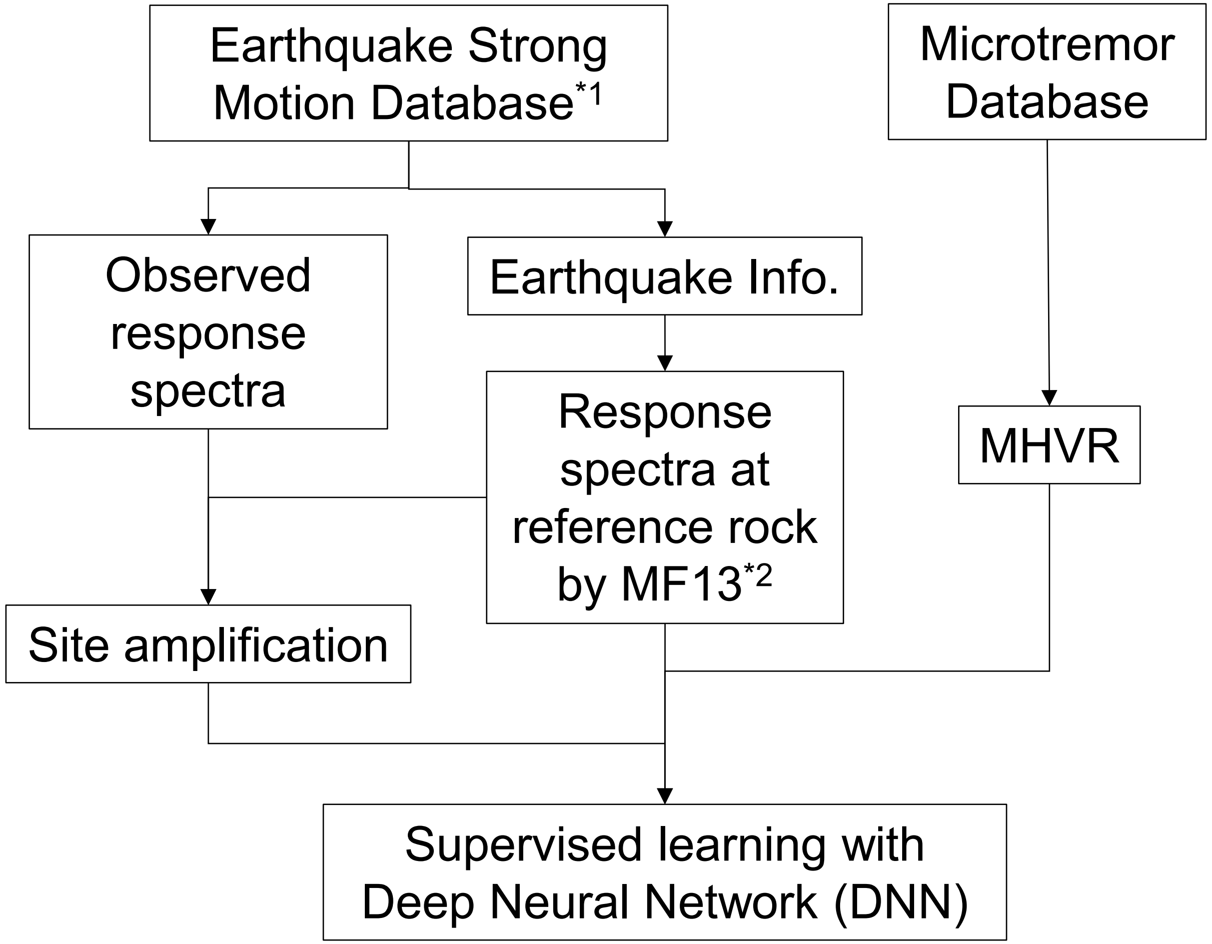
Assessment of Site Amplification Factors in Southern Lima, Peru Based on Microtremor H/V Spectral Ratios and Deep Neural Network

Hiroyuki Miura*,†, Carlos Gonzales**, Miguel Diaz**, Miguel Estrada**, Fernando Lazares**, Zenon Aguilar**, Da Pan*, and Masashi Matsuoka***

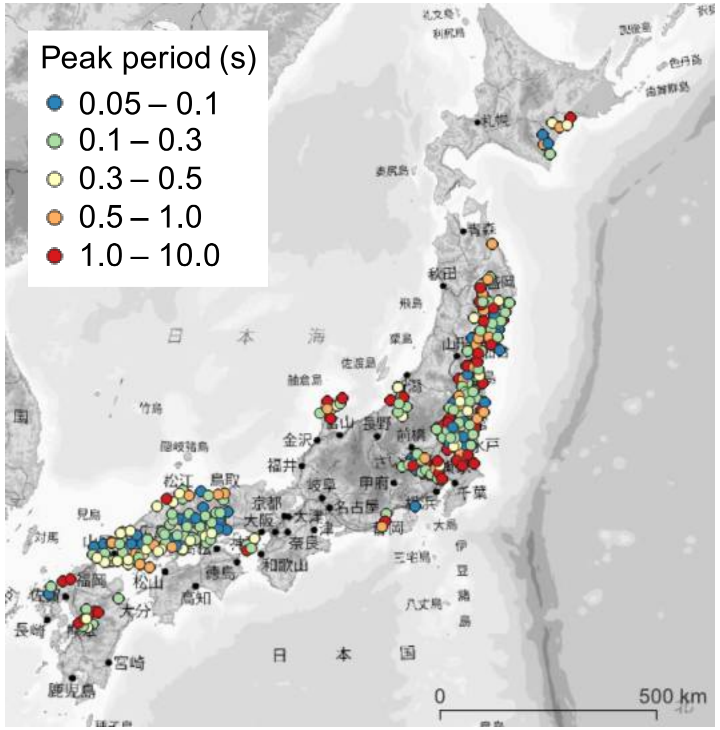
*Graduate School of Advanced Science and Engineering, Hiroshima University
1-4-1 Kagamiyama, Higashi-hiroshima, Hiroshima 739-8527, Japan
†Corresponding author, E-mail: hmiura@hiroshima-u.ac.jp
**Japan Peru Center for Earthquake Engineering Research and Disaster Mitigation (CISMID), National University of Engineering (UNI), Lima, Peru
***School of Environment and Society, Tokyo Institute of Technology, Yokohama, Japan

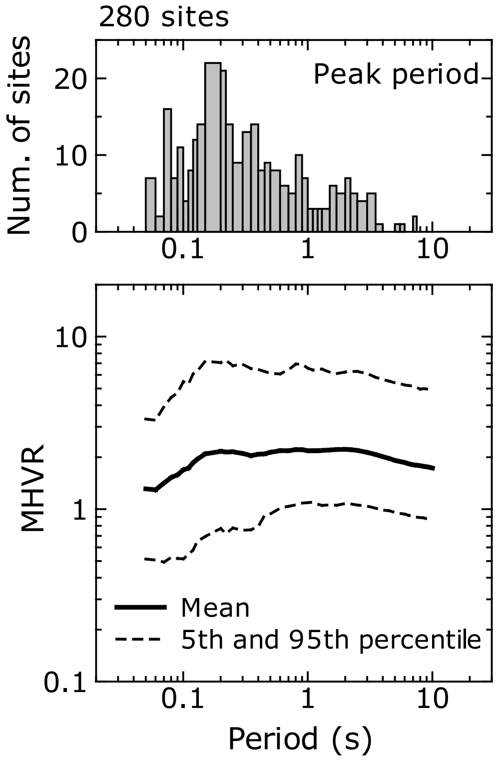
[Received November 30, 2022; accepted March 16, 2023]

Development of MHVR and AI-Powered Ground Motion Model



MHVR Database

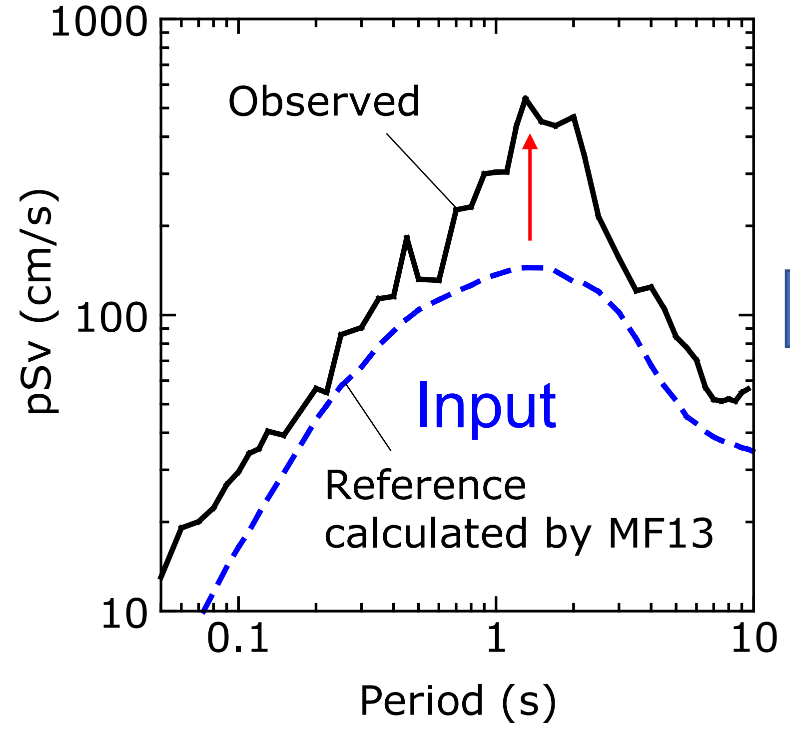


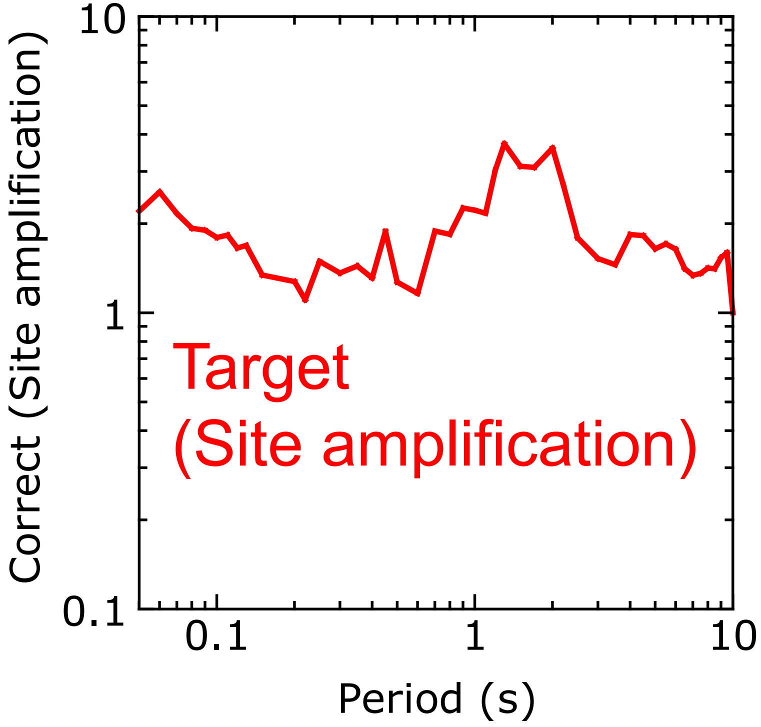


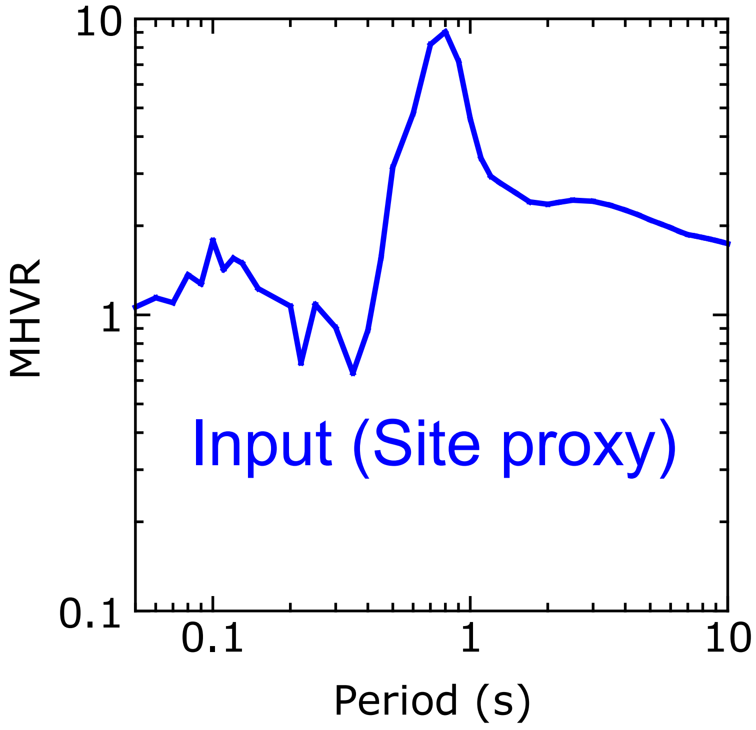
*1 National Research Institute for Earth Science and Disaster Resilience (NIED): *Strong Ground Motion Flat File 2024 version*, https://www.j-shis.bosai.go.jp/en/labs/ground-motion-flatfile/.

*2 Morikawa and Fujiwara: A new ground motion prediction equation for Japan applicable up to M9 mega-earthquake, *Journal of Disaster Research*, 8(5), 878-888, 2013.

Observed Response Spectrum and Site Amplification



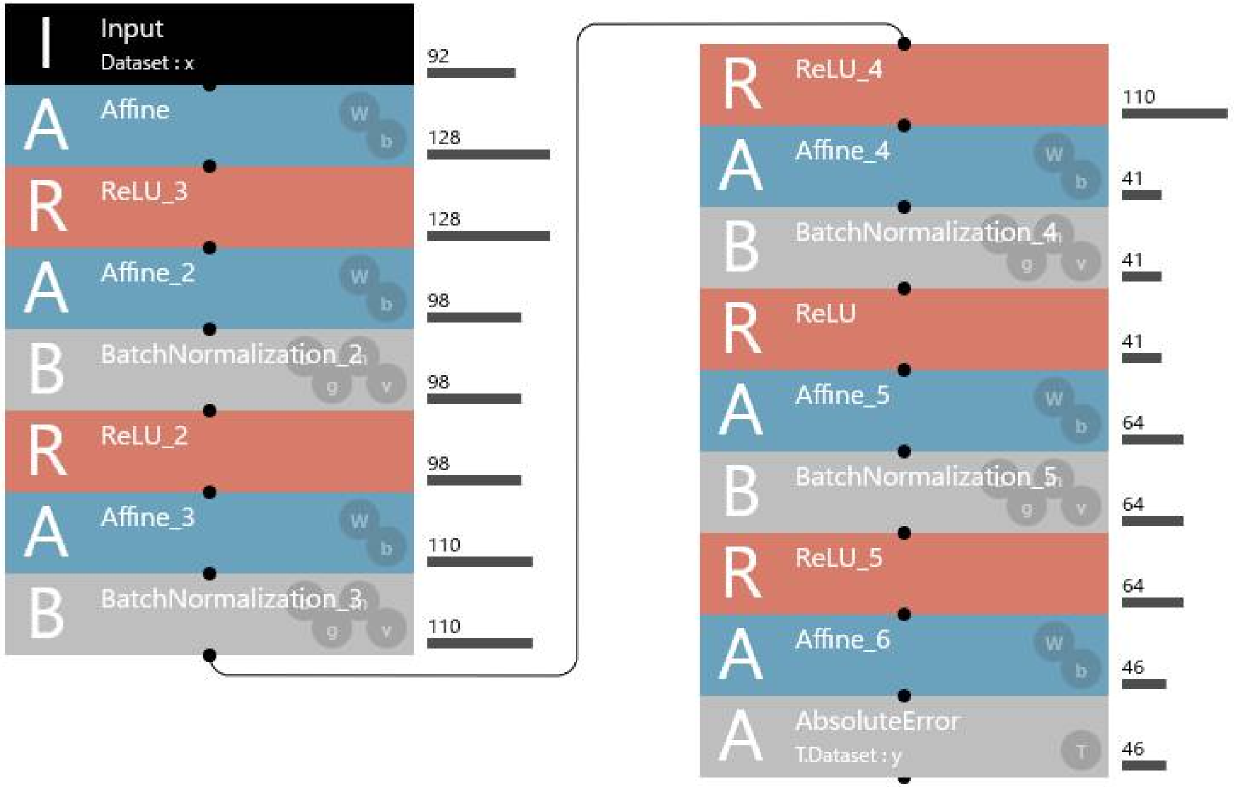




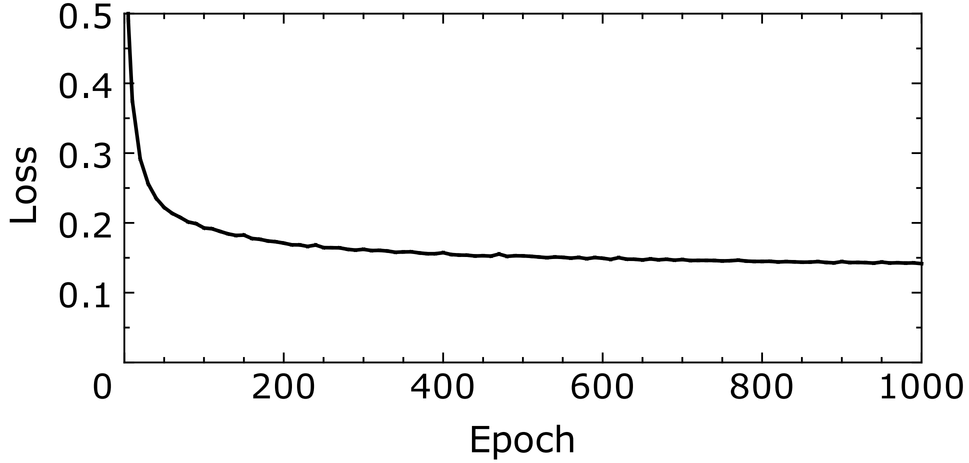
MF13 values are calculated using Mw, Fault distance and earthquake type (Crustal or Inter-plate).

$$Correct_{DNN}(T) = \log(SA_{Obs}(T)) - \log(SA_{MF13}(T))$$

Deep Neural Network Architecture and Training



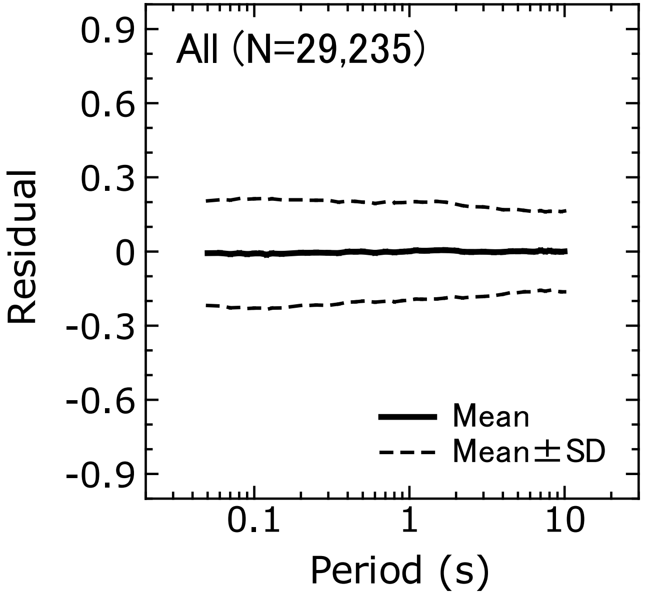
Training data: Records from 1997 to 2023



Input: Response spectra calculated by MF13 and observed MHVR (92 variables)

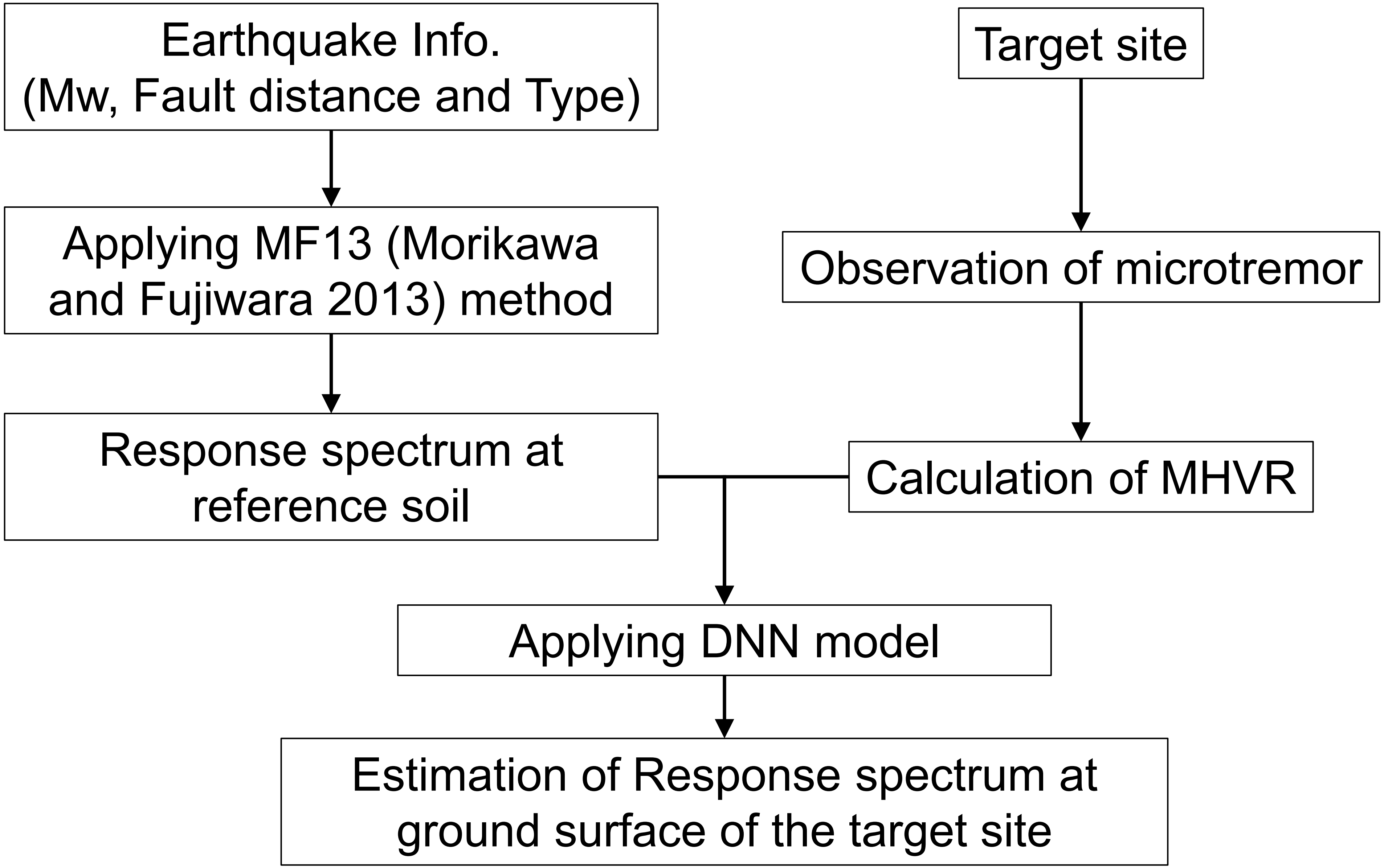
Output: Site amplification ($Correct_{DNN}$) 46 variables

$$Correct_{DNN}(T) = \log(SA_{Obs}(T)) - \log(SA_{MF13}(T))$$

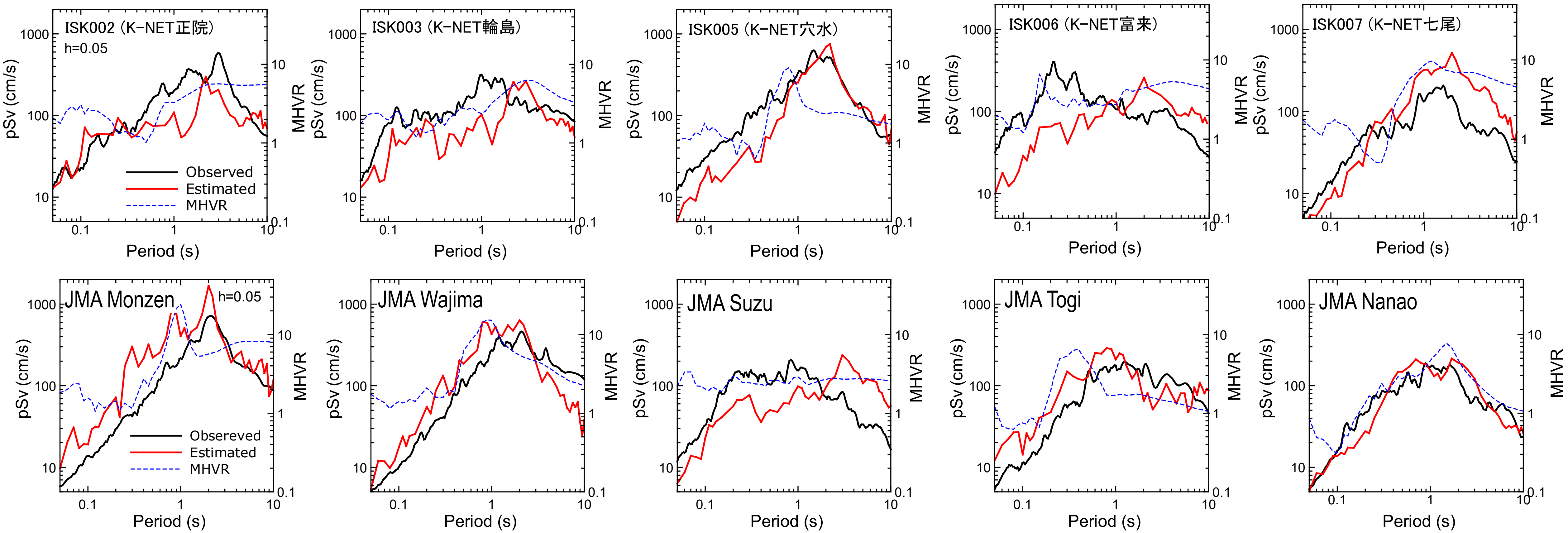


Residual for training samples

Procedure for Estimation of Response Spectrum at Target Site



Estimation of Response Spectra in the 2024 Noto Earthquake (Mw7.5, Crustal)



- Response spectra are well reproduced not only at K-NET (ISK) stations but also at JMA stations where the observed records and MHVRs were not trained in the DNN.
- Significant nonlinear response at ISK005, JMA Monzen and Wajima are also reproduced by the DNN model

Summary

- AI is enhancing earthquake engineering research through the use of observation records.
- Enriching MHVR data is key to achieving more accurate predictions.