



International Conference on Earthquake Engineering

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

EARTHQUAKE RESPONSE OF HIGH-RISE BUILDINGS DUE TO LONG-PERIOD GROUND MOTIONS IN MEGA-CITIES

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Institute of Science Tokyo

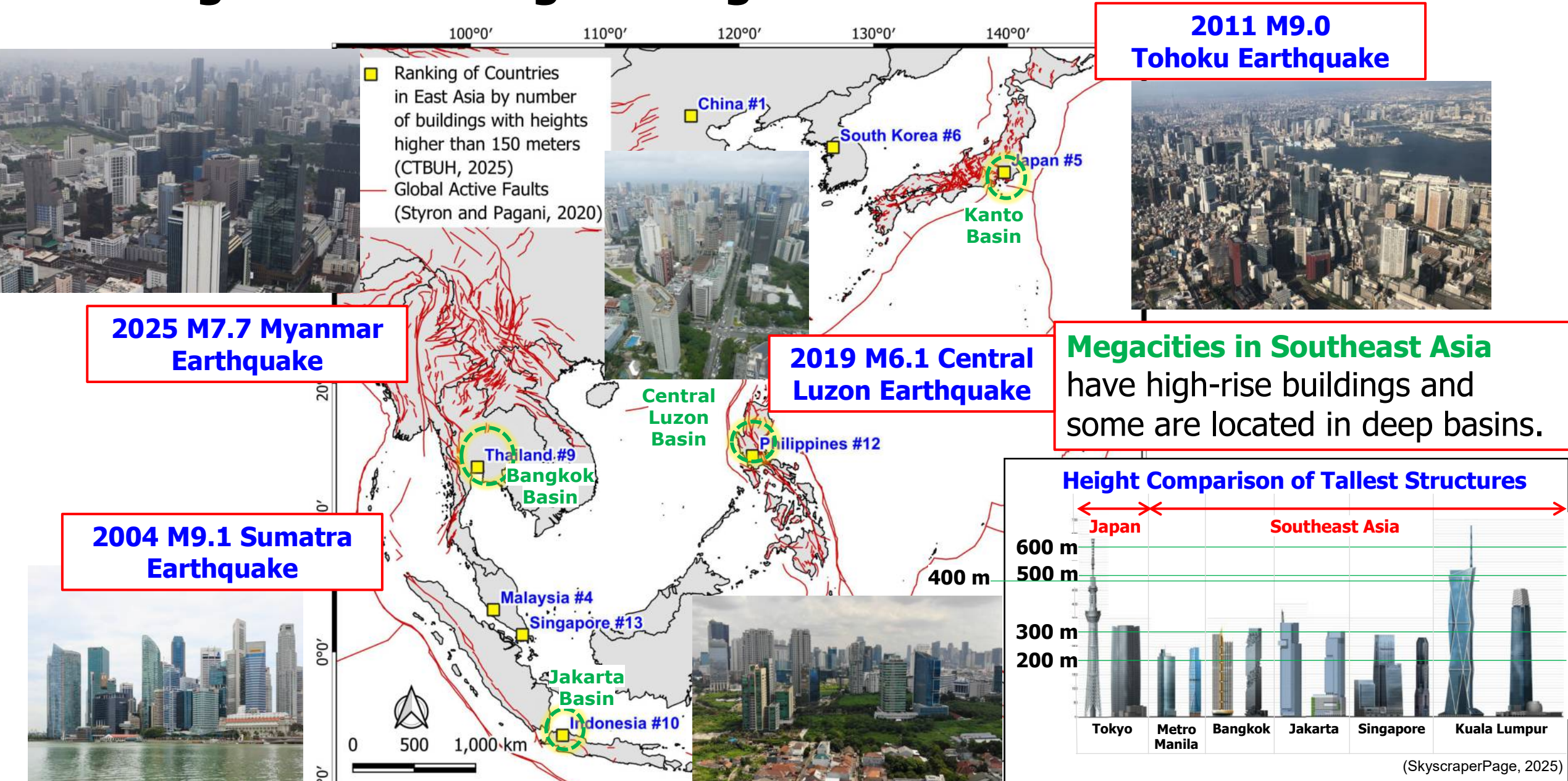
Association for the Development of Earthquake Prediction

August 3, 2026

Earthquake response of high-rise buildings and
long-period motion in Asian Mega city

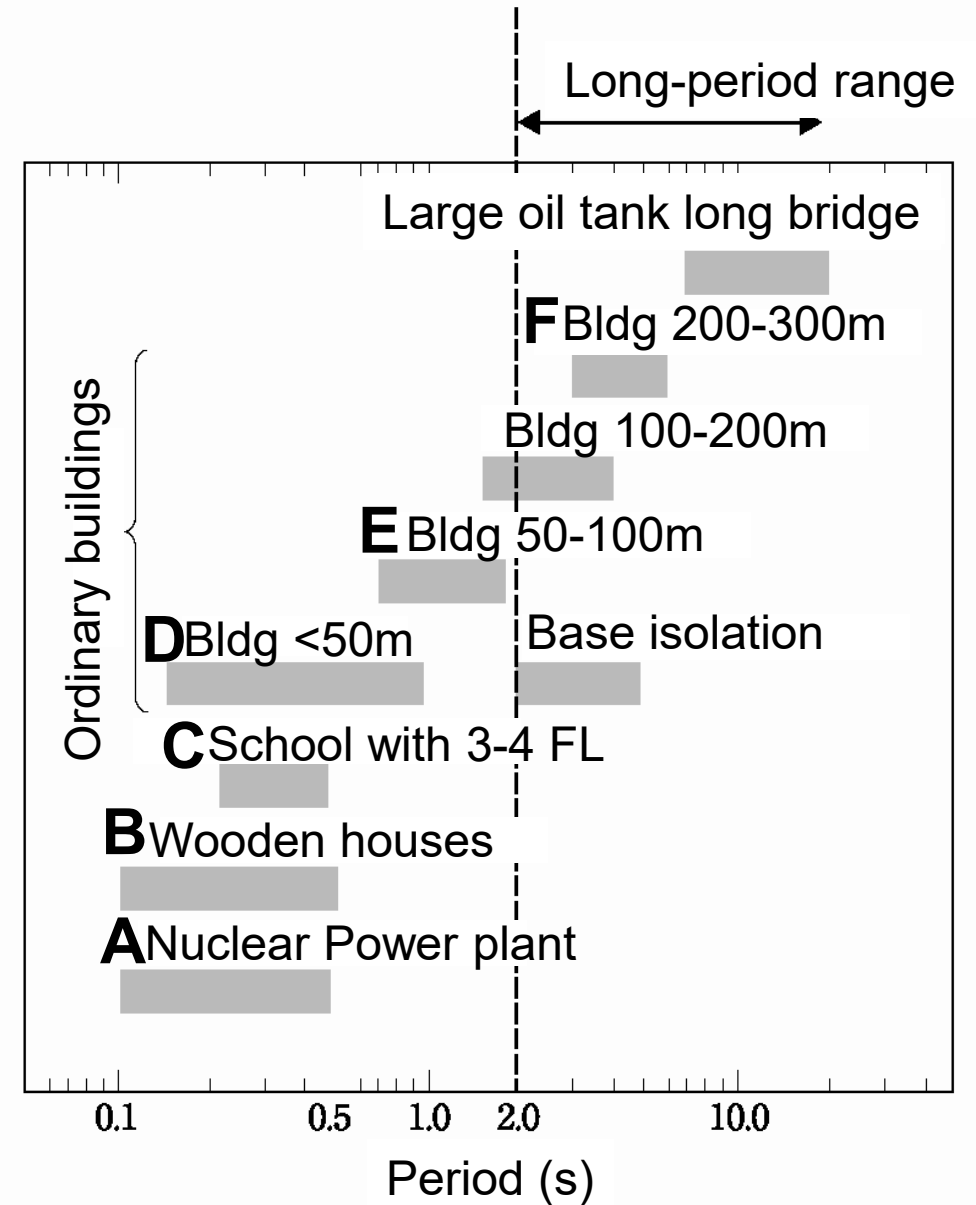
-Observations in Singapore, Tokyo, Manila, Bangkok-

High-rise buildings in Megacities of Southeast Asia



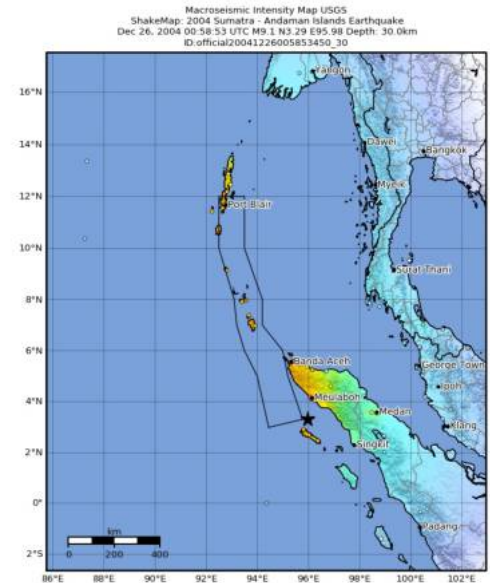
What is the response of affected high-rise buildings during these earthquakes?

Long natural period and low damping factor



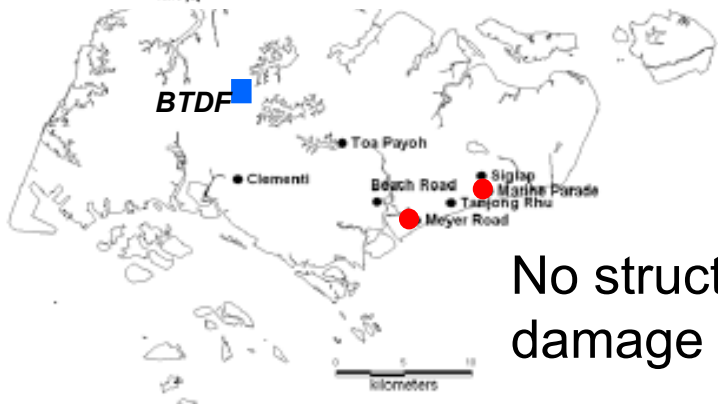
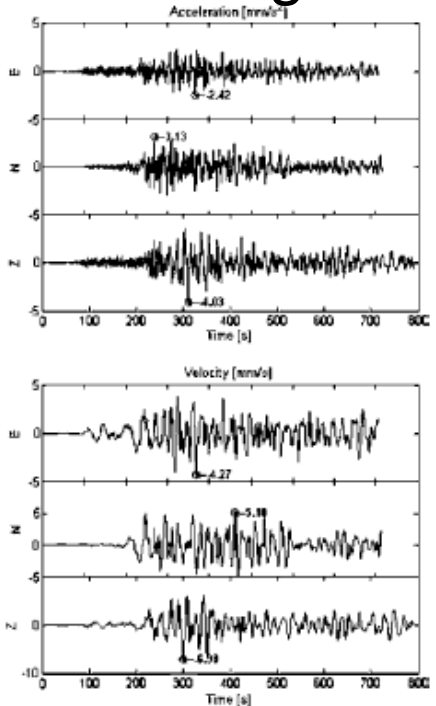
Tall buildings in Singapore during 2004 Sumatra earthquake

550 bldgs. with height > 100m



SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(g)	<0.046	0.097	2.76	6.2	11.5	21.5	40.1	74.7	>139
PGV(cm/s)	<0.021	0.135	1.41	4.65	9.64	20	41.4	85.8	>178
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X

Scale based on Worden et al. (2012) Version 1: Processed 2020-06-03T04:47:06Z
Seismic Instrument - Reported Intensity * Epicenter □ Rupture



No structural damage observed

Figure 1. Distribution of locations in Singapore where tremors were felt (Pan et al., 2006)

Tremors felt in many parts of Singapore

TREMORS were felt in many parts of Singapore early yesterday morning as a result of the massive earthquake that struck Indonesia's Sumatra island.

But the tremors – which were felt in Tanjong Rhu, Marine Parade, Toa Payoh, Siglap and Meyer Road – were mild and caused no damage or casualties.

Mrs Mary Lim, a resident of Laguna Park on the east coast, told TODAY that she knew something was not right when the chandeliers in her apartment began swaying.

She said: "My balcony sliding doors were open and there was no breeze coming through."

"Then, the chandeliers just started swaying and some of the ornaments in my showcase also began shaking."

"It was quite scary and I decided to just go to the void deck as a precaution."

Police spokesman Tan Soon Aik said the police received about 13 calls from



Villagers in Colombo, Sri Lanka examining the debris of their homes, which were destroyed yesterday by tidal waves.

the affected areas, but no injuries were reported.

Meanwhile, the Ministry of Foreign Affairs (MFA) said their overseas missions in tidal wave-hit Sri Lanka, India, Thailand and Bangladesh were in touch with the local authorities as a result of the Indonesian earthquake.

In a statement, the MFA said it would provide assistance to Singaporeans in the affected areas. It also urged Singaporeans travelling or staying within the region to continue to monitor developments and to register with the nearest Singapore embassy or consulate.

They can also register through the ministry's website at www.mfa.gov.sg/consular

Relatives or friends of Singaporeans who are in the affected areas can call the MFA Duty Office at 6332 0000 to register their contact details. – Jose Raymond

TODAY, 27 December 2004

High-rise buildings in Japan

1968



1991



2007



2022



Tokyo 180
Saitama 73
Chiba 70
Kanagawa 169
Aichi 80
Osaka 221
Hyogo 98

492
in Kanto
basin(C)

319
in Osaka
basin(A)

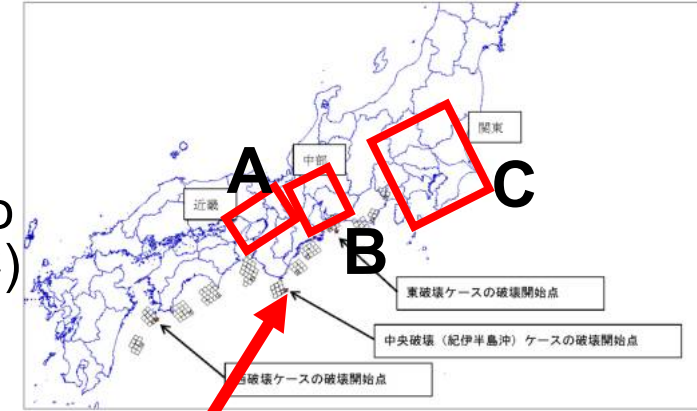
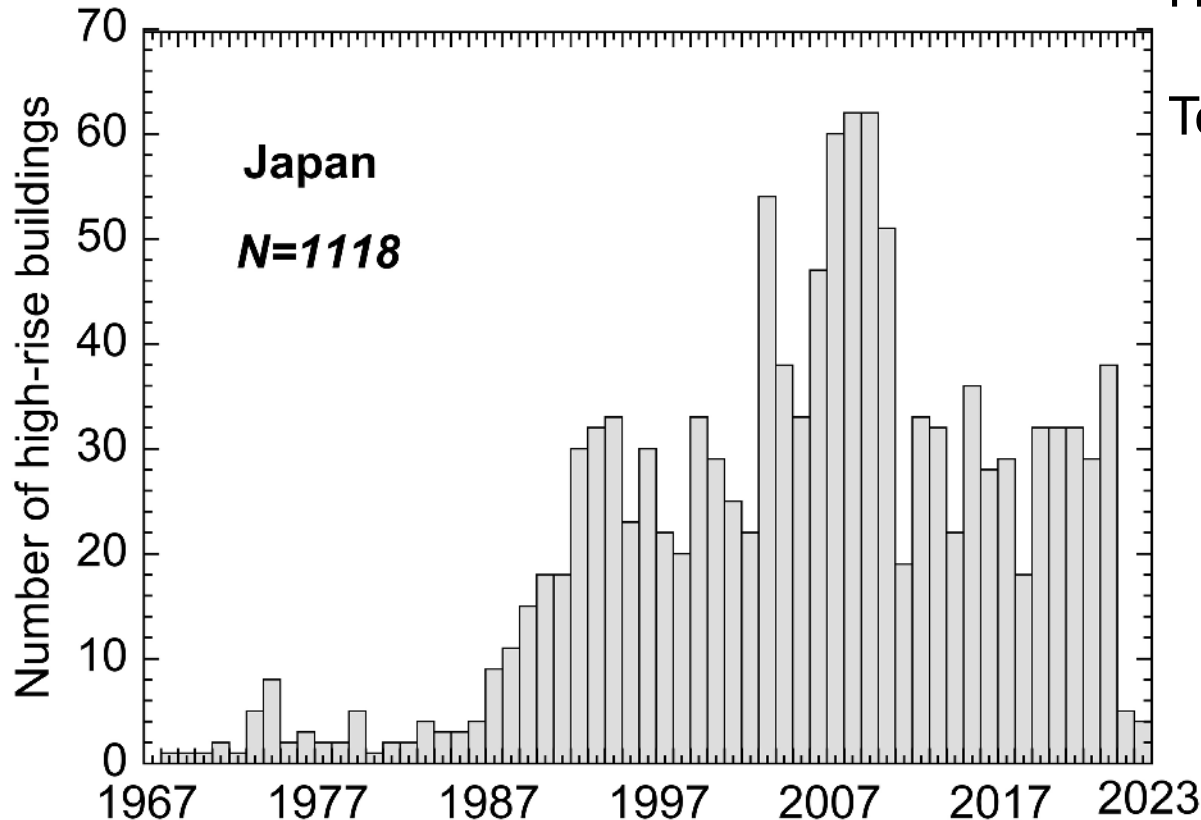
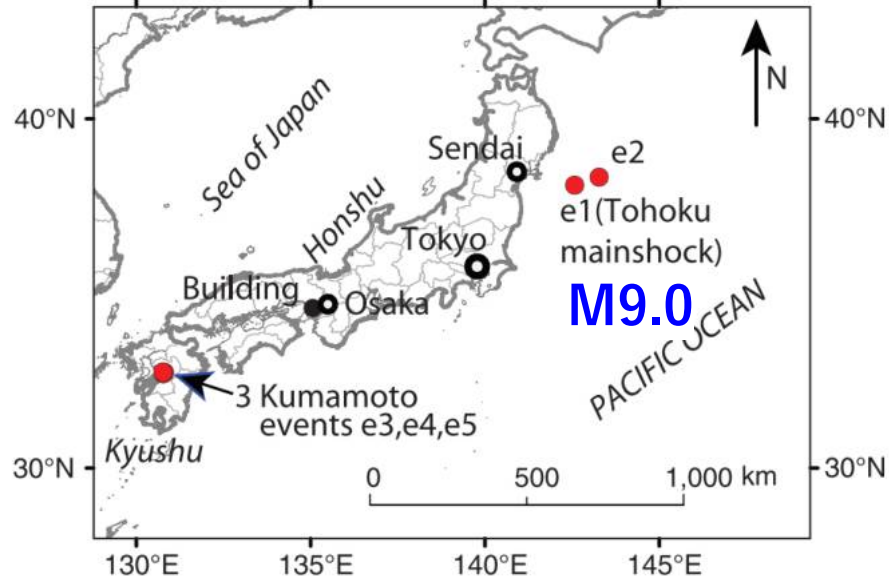


図7. 東破壊、西破壊の破壊開始点と評価範囲 (SMGAは最大クラスのSMGA分布を表示)

Total 891(80%) in 3 basins



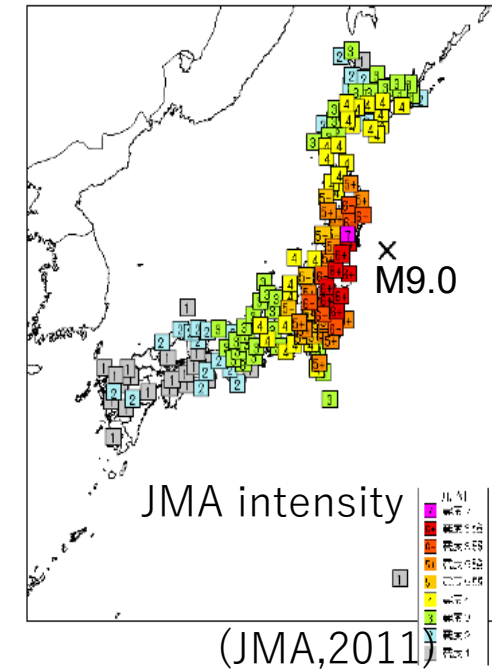
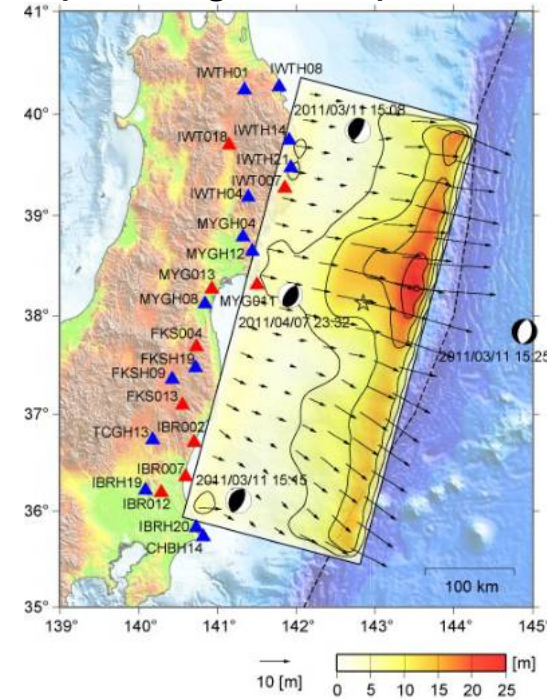
High-rise Buildings in Tokyo during 2011 Tohoku earthquake



Damage to high-rise buildings in Tokyo (400 km) and Osaka (767 km)

(Hisada et al., 2012; Kashima et al., 2015; Celebi et al., 2017)

Large slip in large fault plane



Earthquake impact inside a building



Falling of books
Kubo et al., 2014

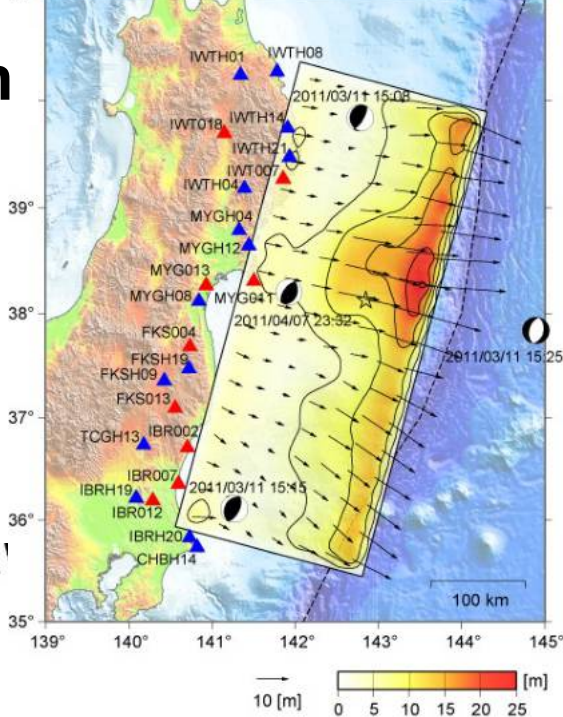
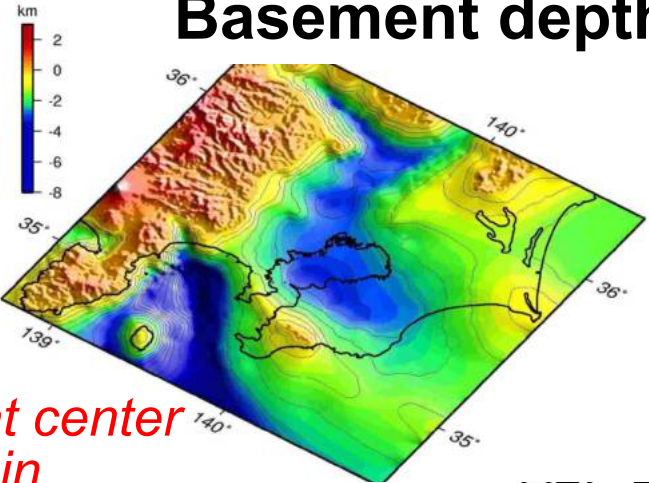


Overturning of Shelves
Kubo et al., 2014

Far-field earthquakes can influence high-rise building responses in deep basins.

Long-period ground motion of 2011 Toho earthquake

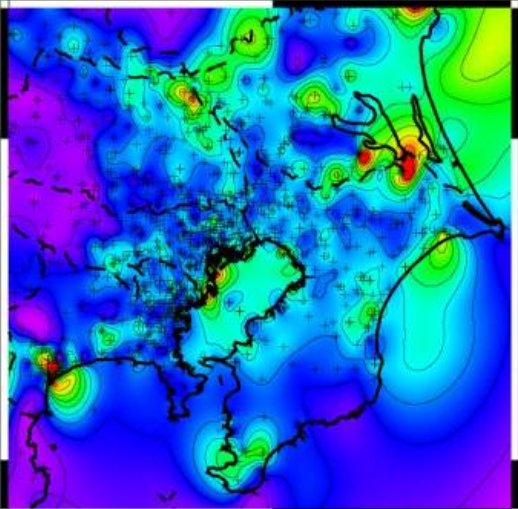
Basement depth



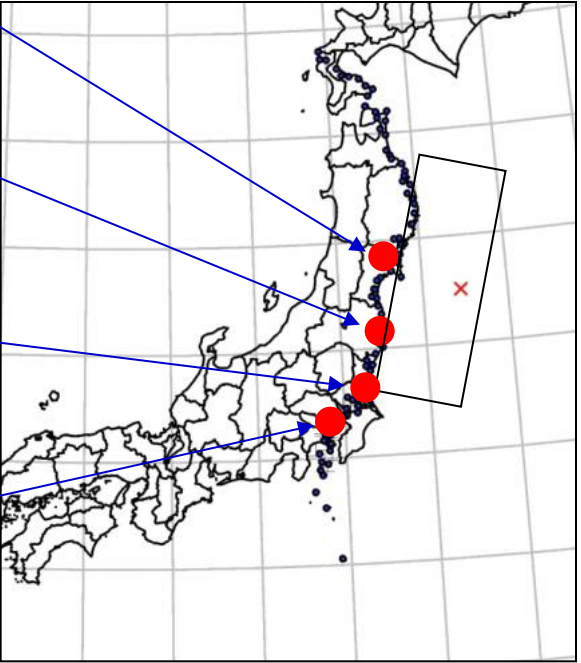
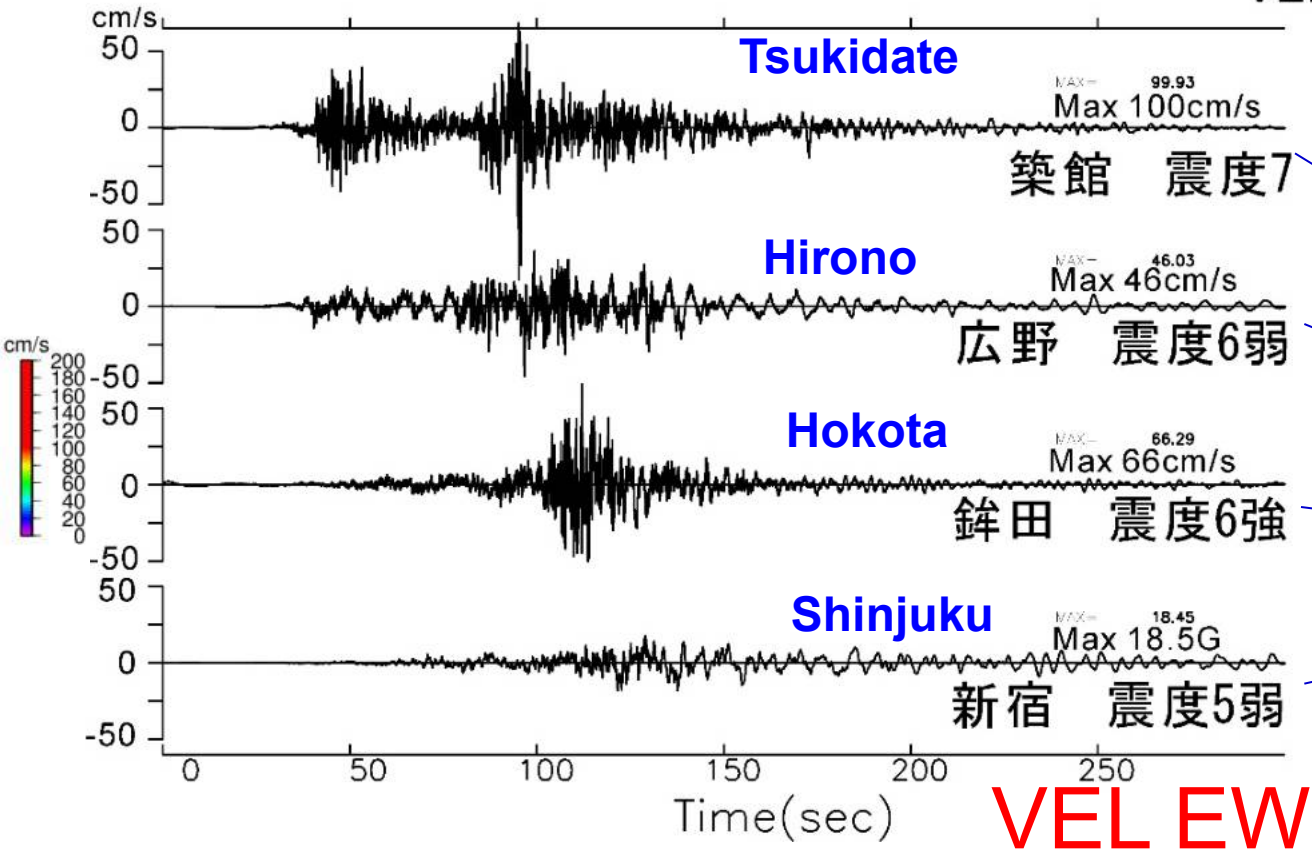
Surface wave generation in a basin

Shinjuku is at center of Kanto basin

PSV at T=2sec

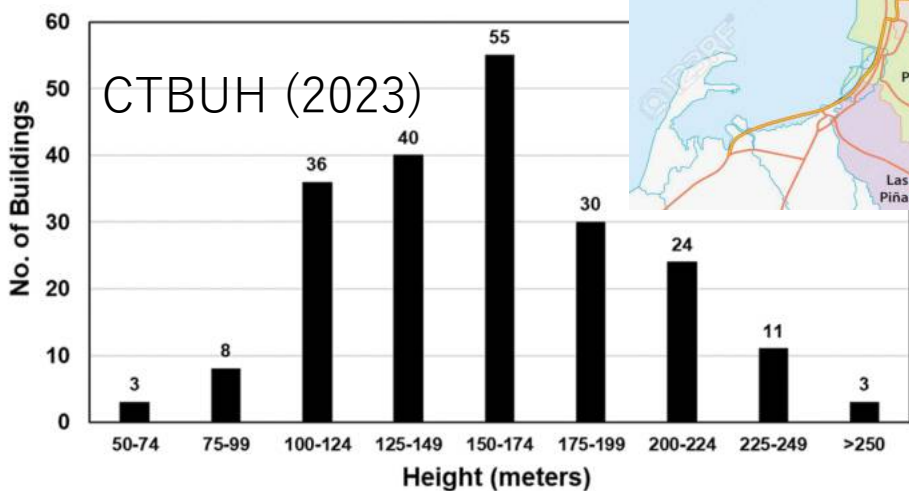
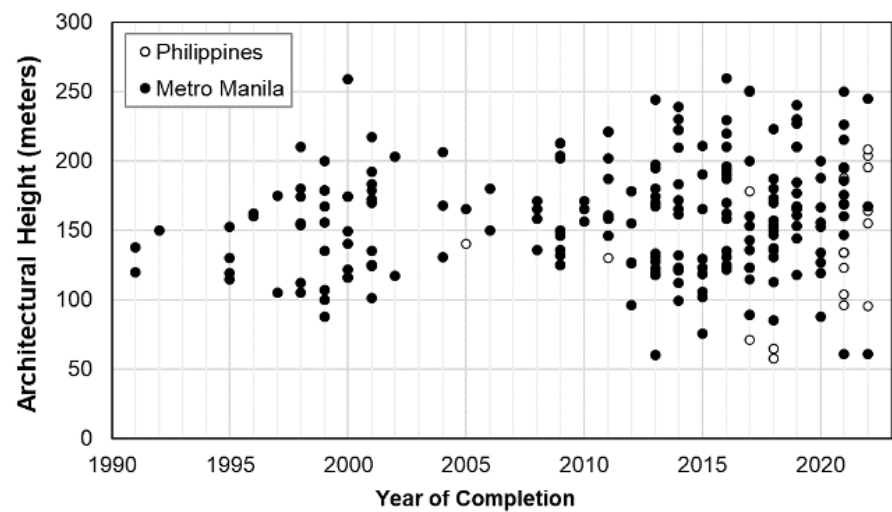


two major parts, large amplitudes long duration



High-rise buildings in Metro Manila, the Philippines

Tall buildings are limited in some areas, such as Makati, Taguig, Mandaluyong



Tallest:
Metrobank Center
(66F, 318m)



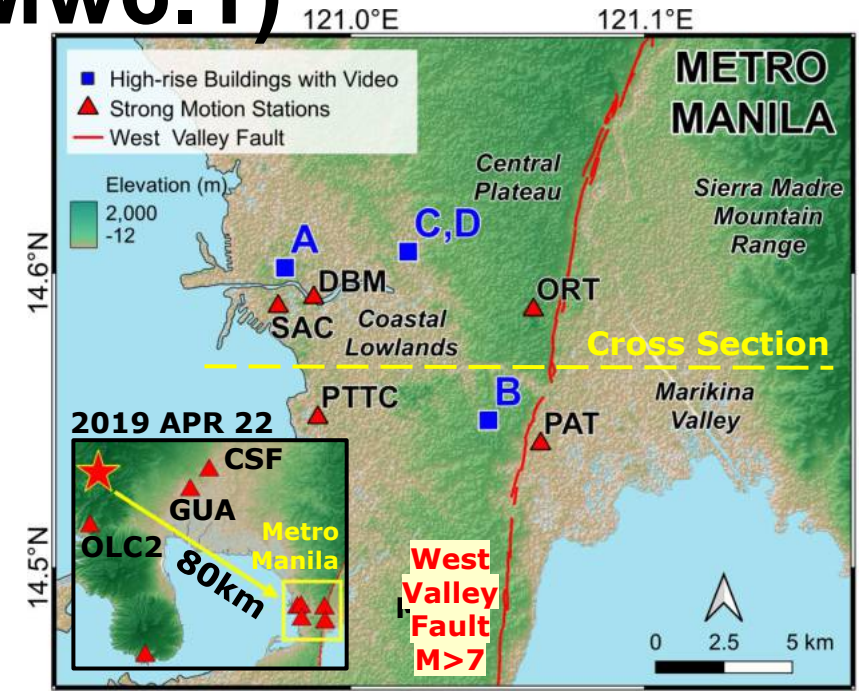
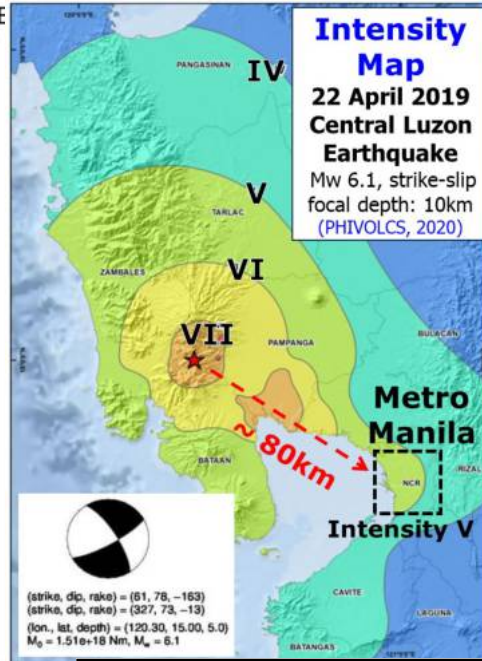
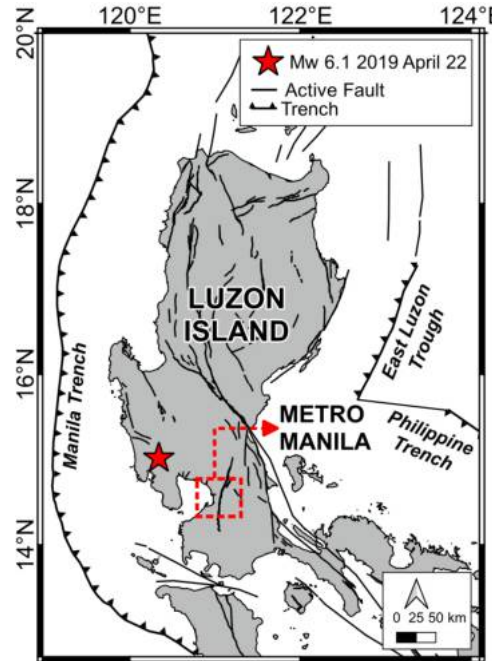
METRO MANILA

199 bldgs. with height >100m



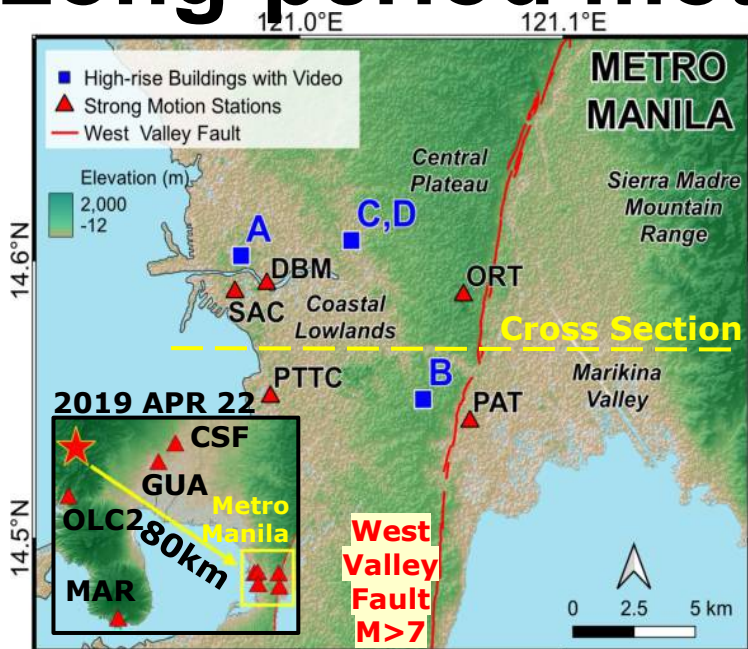
Central Luzon earthquake (Mw6.1)

Metro Manila

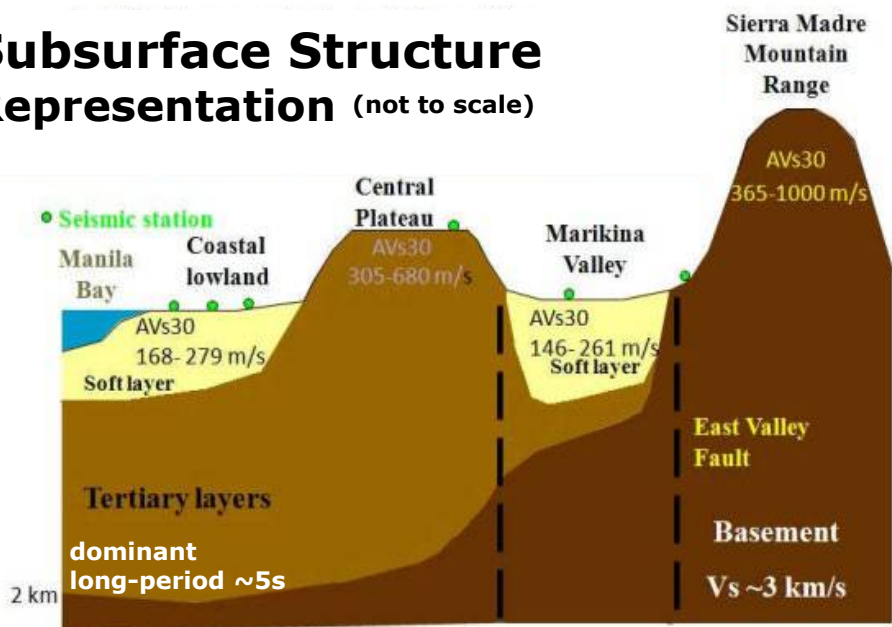


Why did this moderate size earthquake cause **nonstructural damage** to high-rise buildings in Metro Manila?

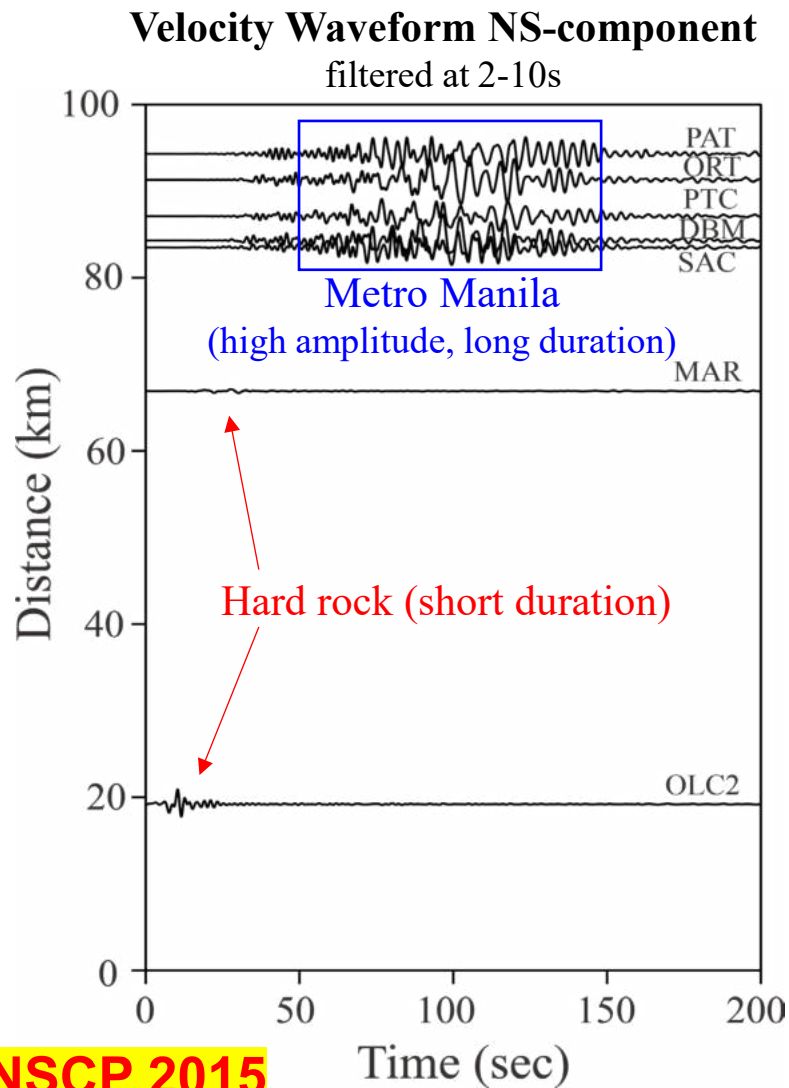
Long-period motion in Manila



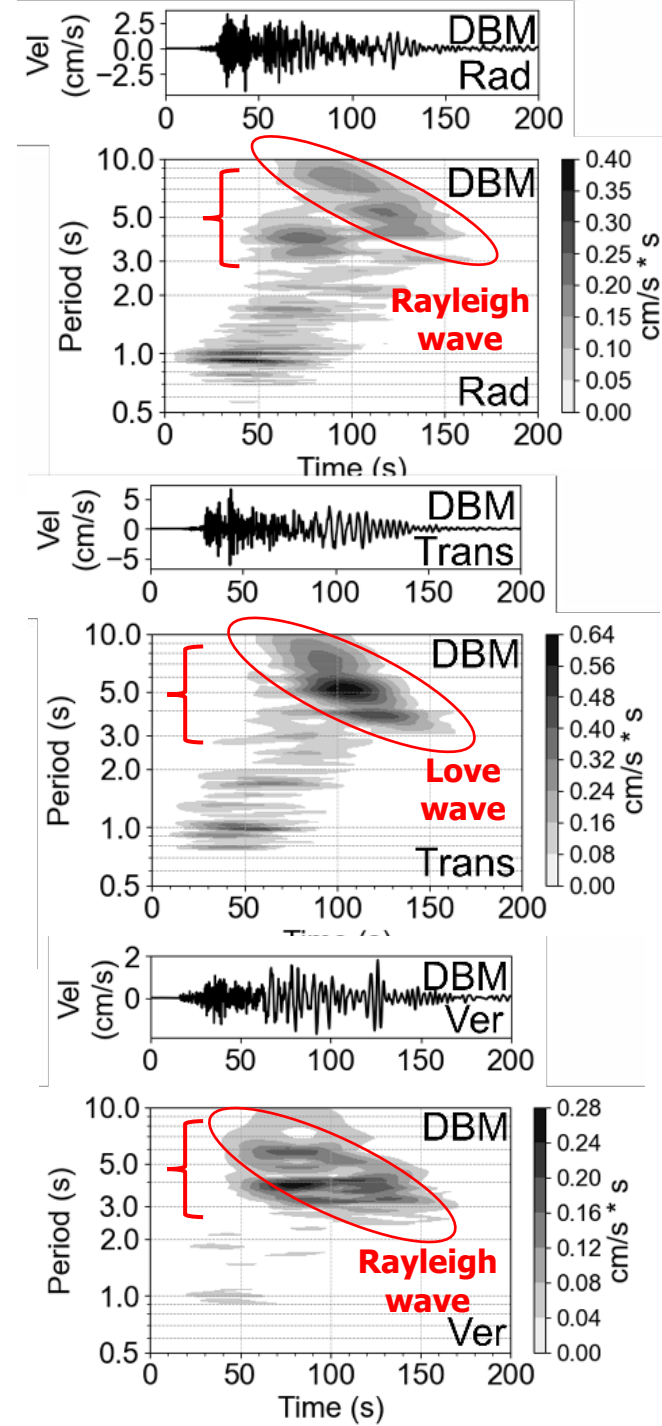
Subsurface Structure Representation (not to scale)



(Grutas & Yamanaka, 2011)

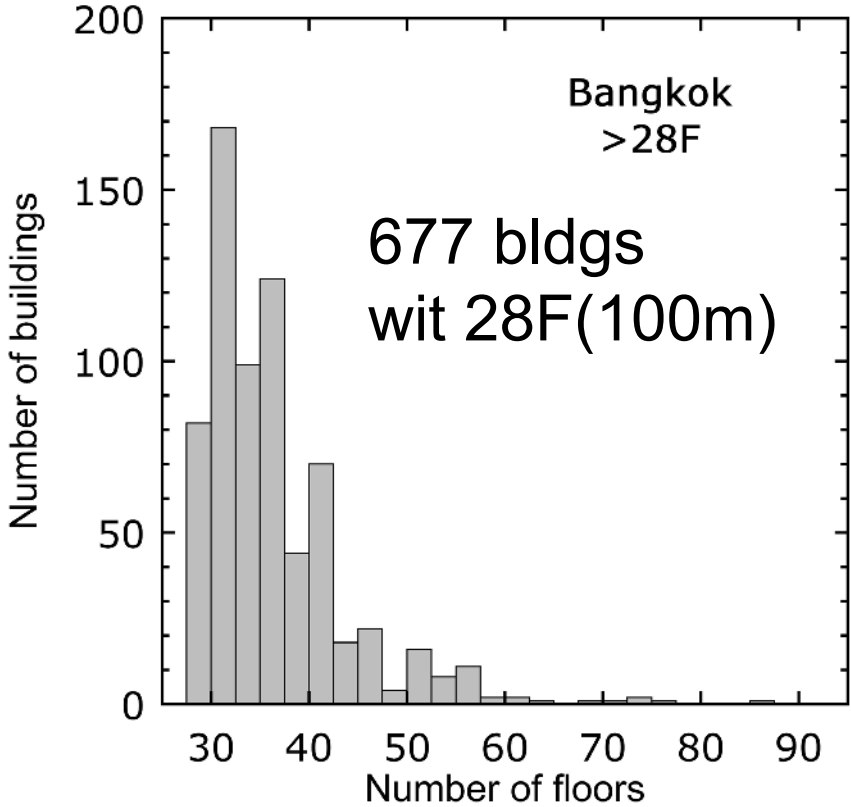
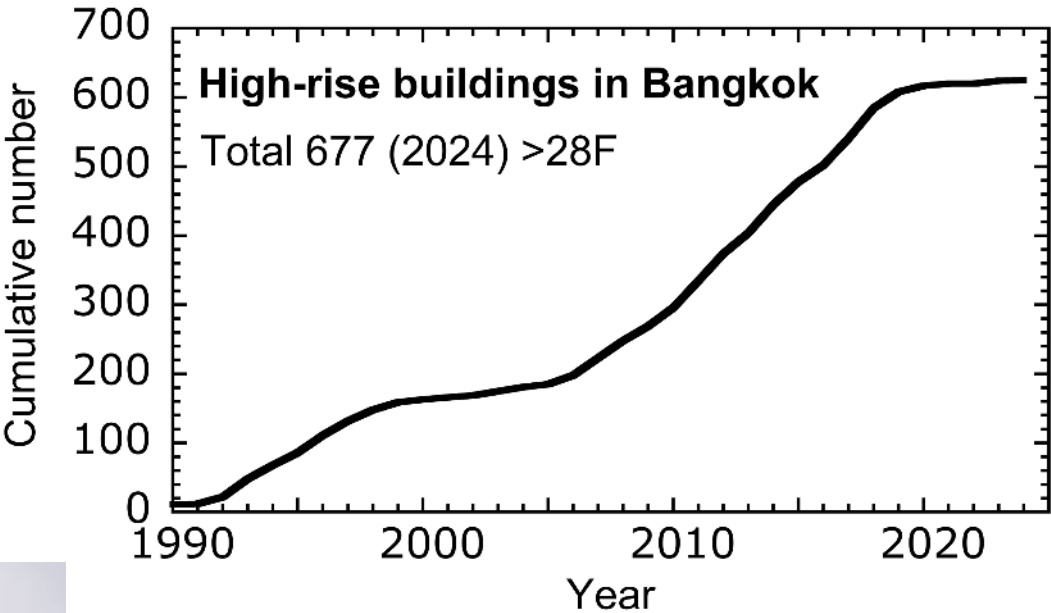
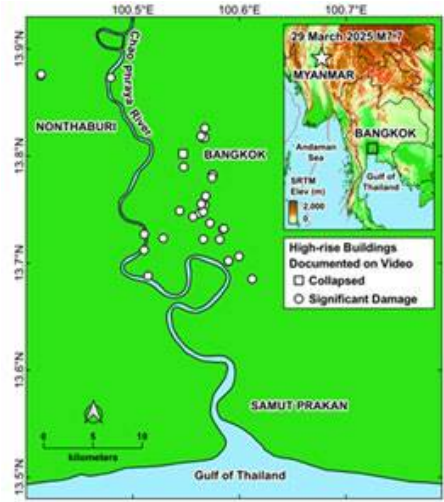


NSCP 2015
DOES NOT ACCOUNT
Deep Sedimentary Layers
 (Peñarubia et al., 2020)



High-rise buildings in Bangkok

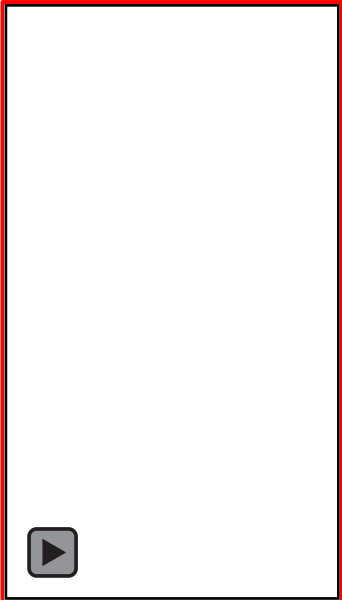
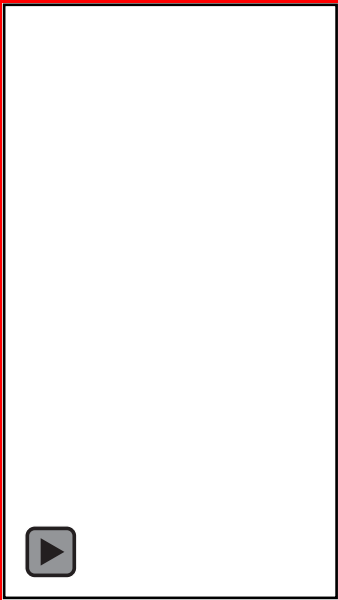
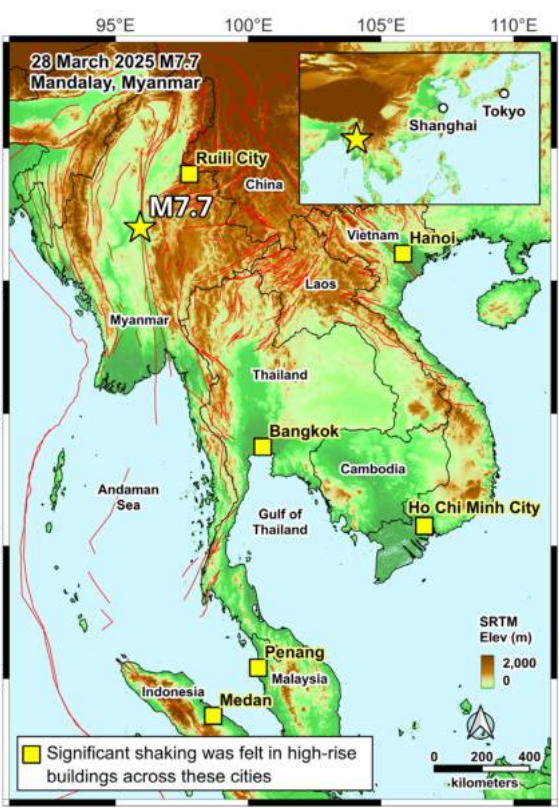
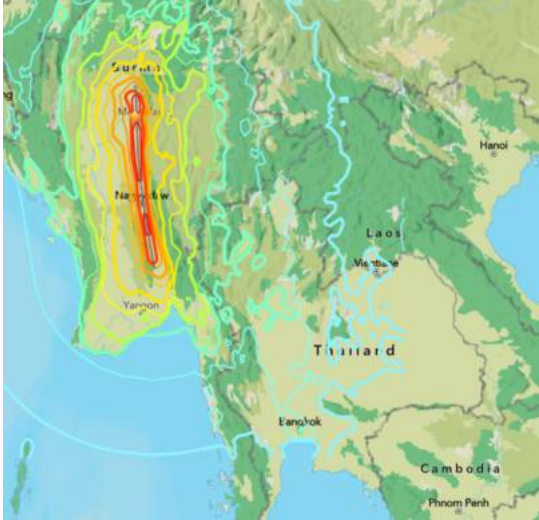
Typical Mega city in SE Asia
Highest : 318m(70F),314m(78F)
Seismic design from 2007



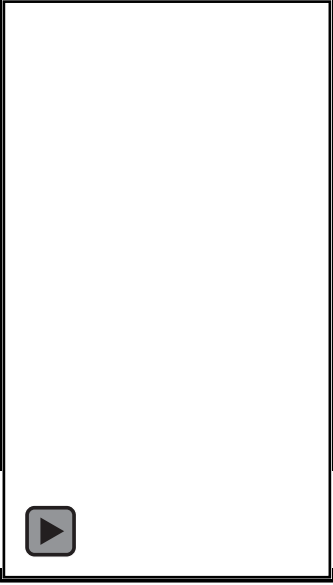
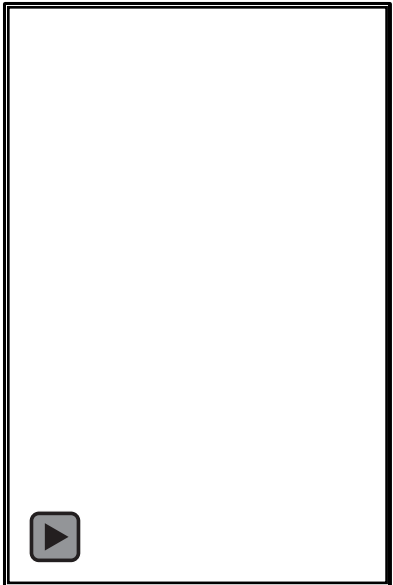
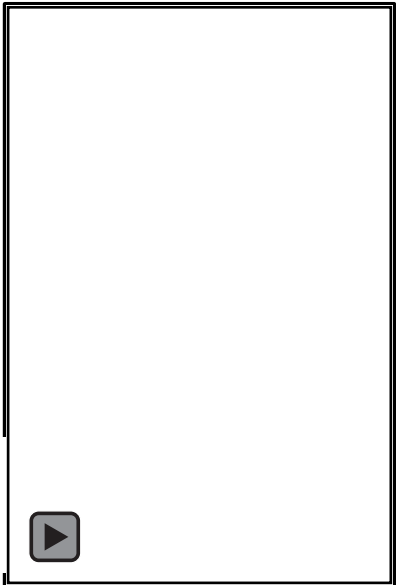
High-rise buildings during the 2025 Myanmar earthquake

The 2025 Myanmar earthquake (M7.7) caused damage to high-rise buildings in Maga cities in southeast Asia including Bangkok, more than 1,000 km away. Buildings under-construction collapsed, resulting in casualties. Water overflowed from pools on the roofs of high-rise buildings.

- 2025-03-28 12:50 (local time)
- Mw 7.7, Depth: 10km
- Vertical right-lateral faulting along Sagaing fault
- Length:400km, Max disp:6m
- Max intensity:IX(MMI), More than 2000death

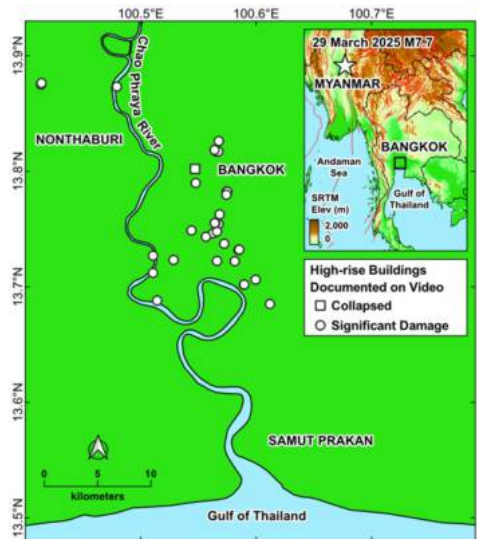


Bangkok, Thailand

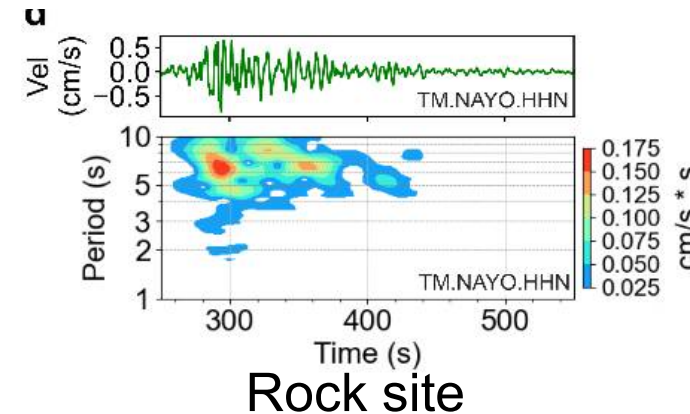
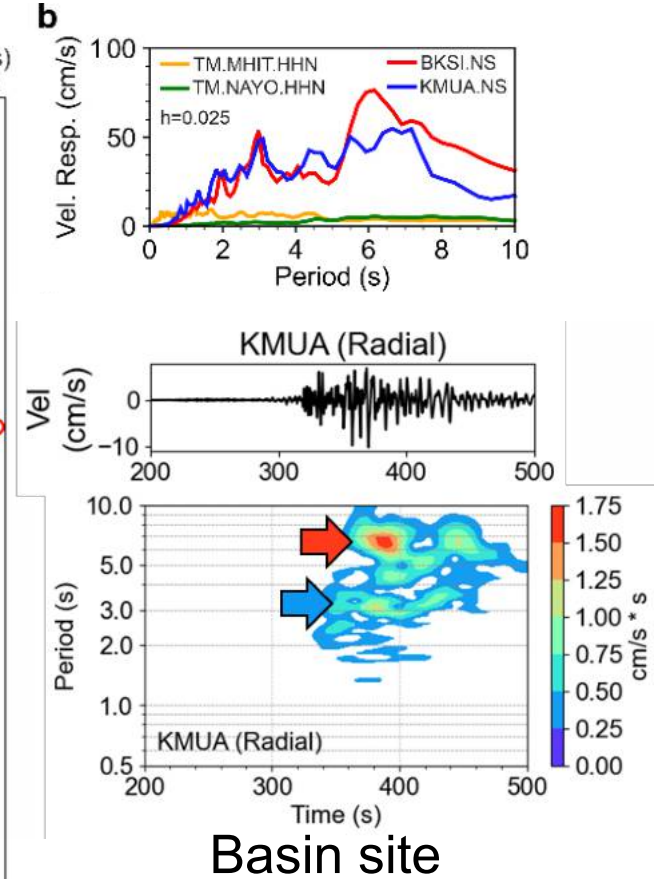
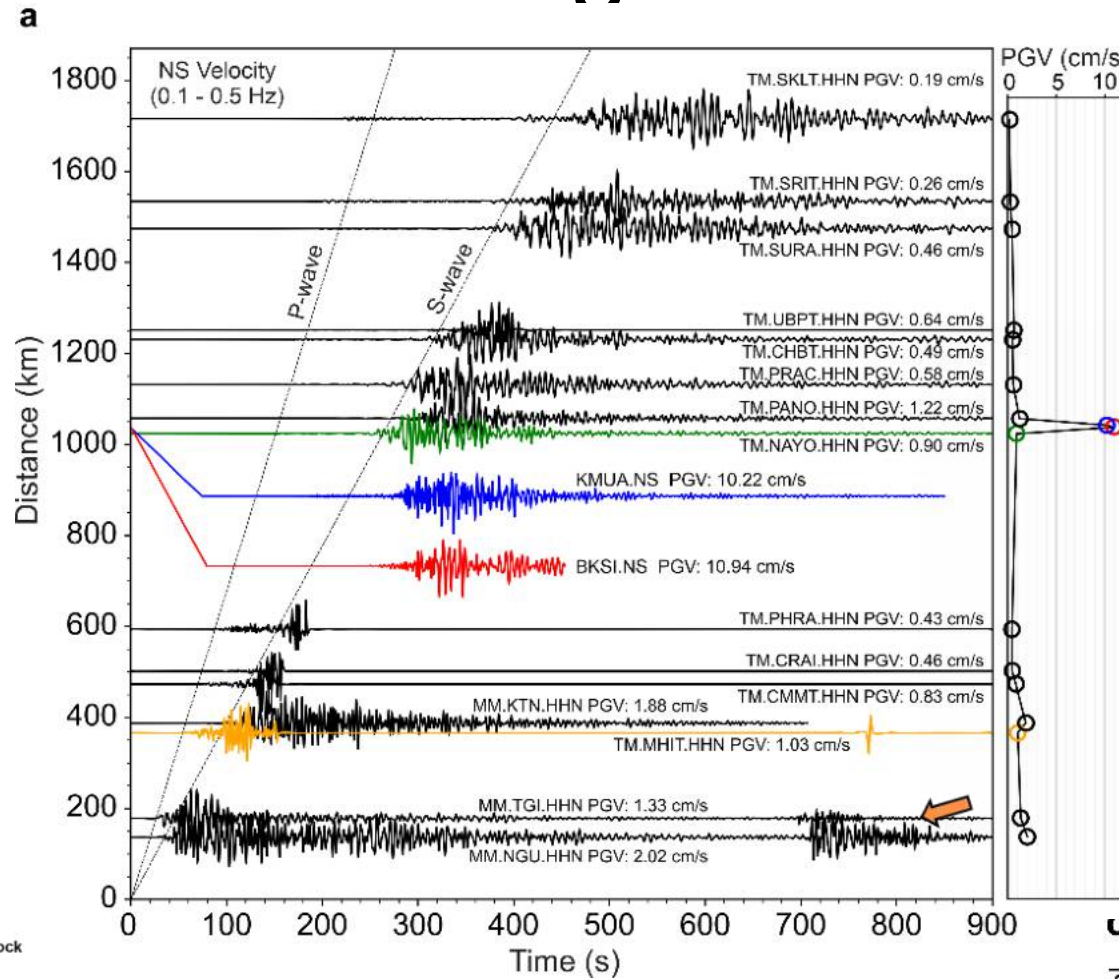
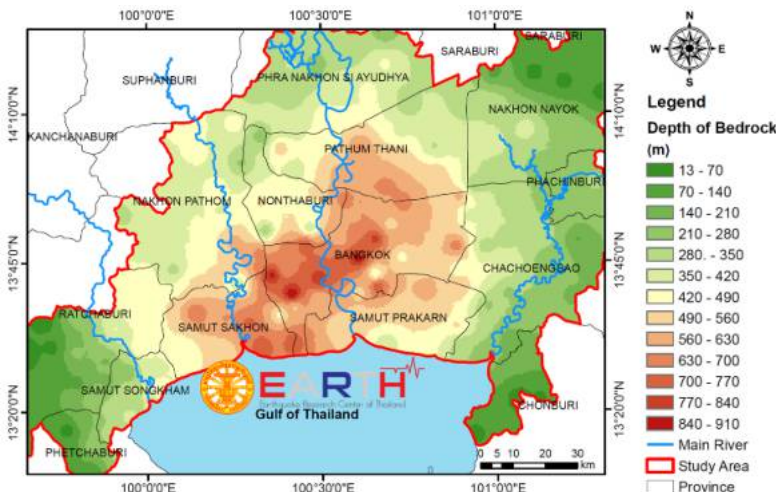
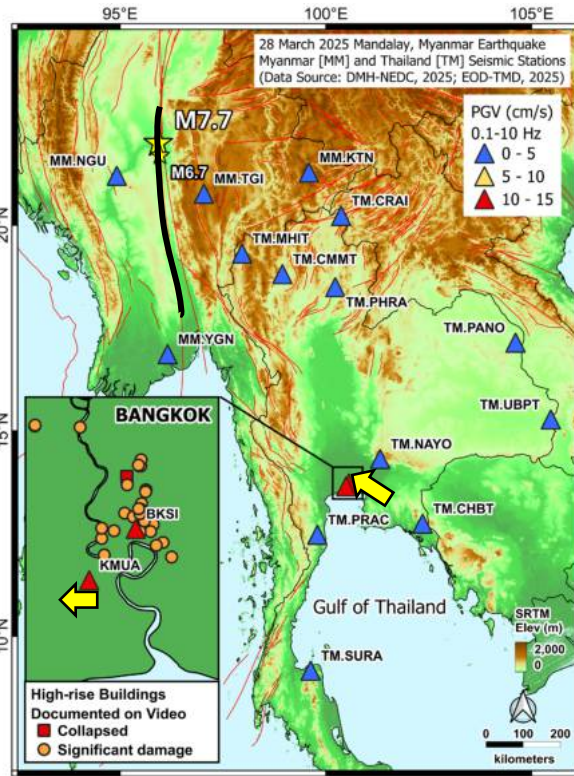


Tall buildings in Bangkok during Myanmar earthquake

- Non structural damage
- Connecting corridors between buildings, partition wall, outer wall
- water spillage from rooftop pool
- Building under-construction was collapsed. More than 90 people killed



Features of observed ground velocities



Long-lasting long-period motion by
**source (rupture time=120s) and
site effects**

Shaking maps in Japan by HERP

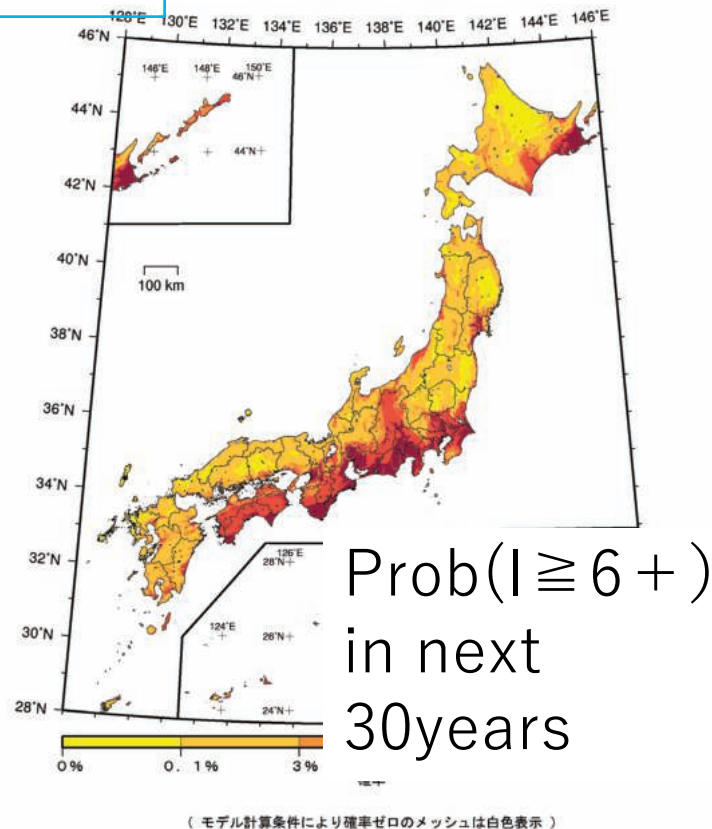
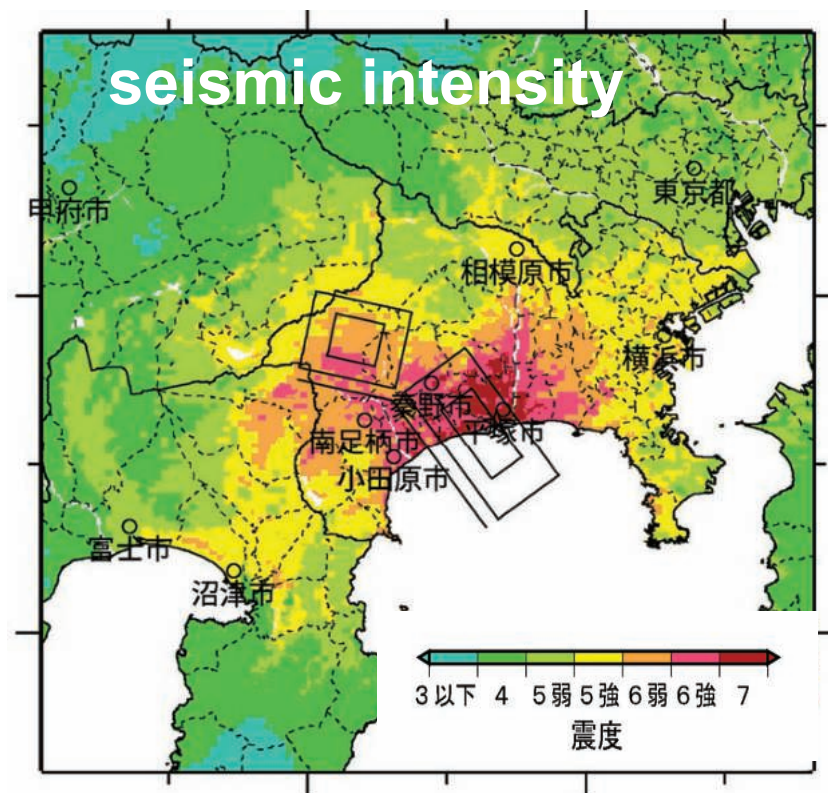
- Effort to build database for strong motion prediction in Japan over 25 years-

Activities in HERP

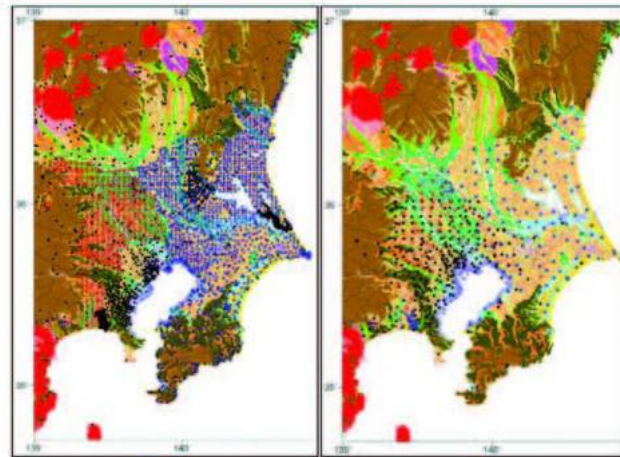
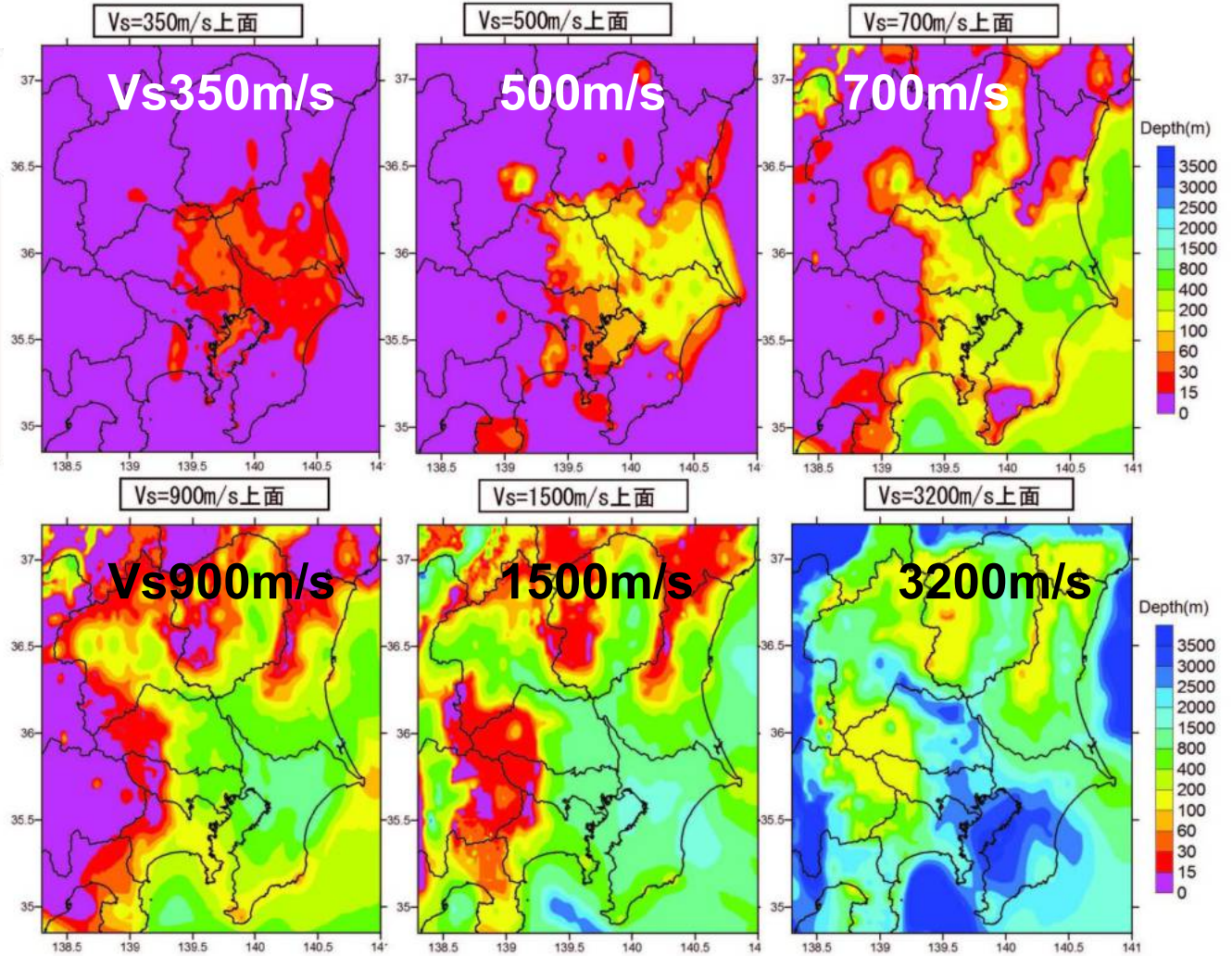
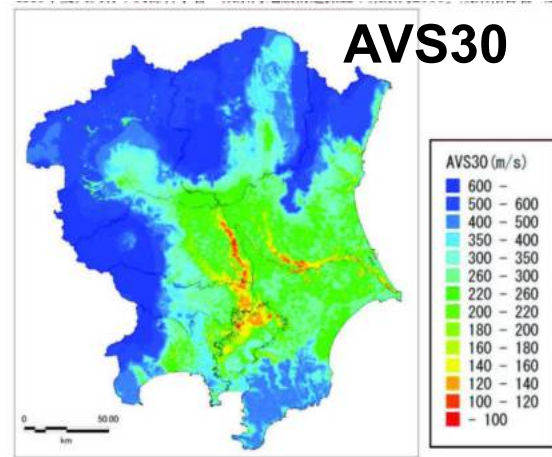
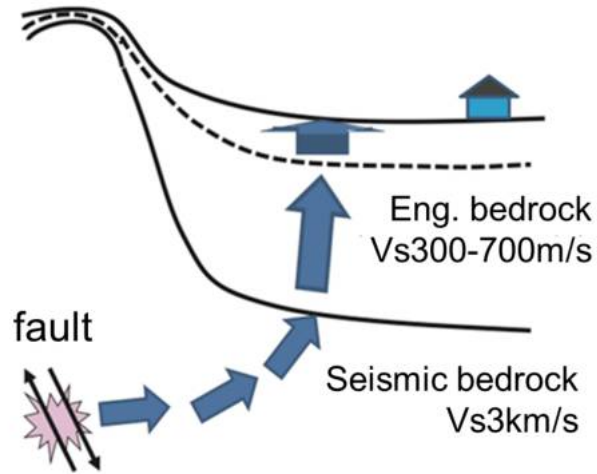
Headquarters for Earthquake Research Promotion established in 1995 to promote research into earthquakes for reduction of damage and casualties from earthquakes.

Earthquake Research Committee and Policy Committee in HERP

- Long-term evaluation for possible earthquakes → *Earthquake source models*
- Probabilistic seismic Hazard map } Subcommittee for evaluation of strong ground motion
- Scenario earthquake hazard map } *WG for strong motion evaluation techniques*
- Evaluation of tsunami hazard } *WG for subsurface structural model*



3D model of shallow and deep soil layers in Tokyo



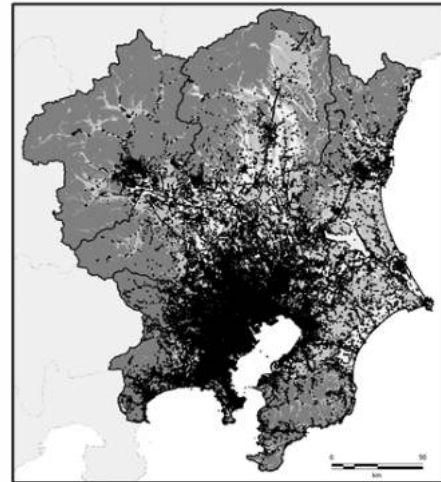
H/V, Phase Velocity

Miniature and Small size
Array Observation
(Kanto Area: 12,000 points)
about 1 km intervals

Phase Velocity

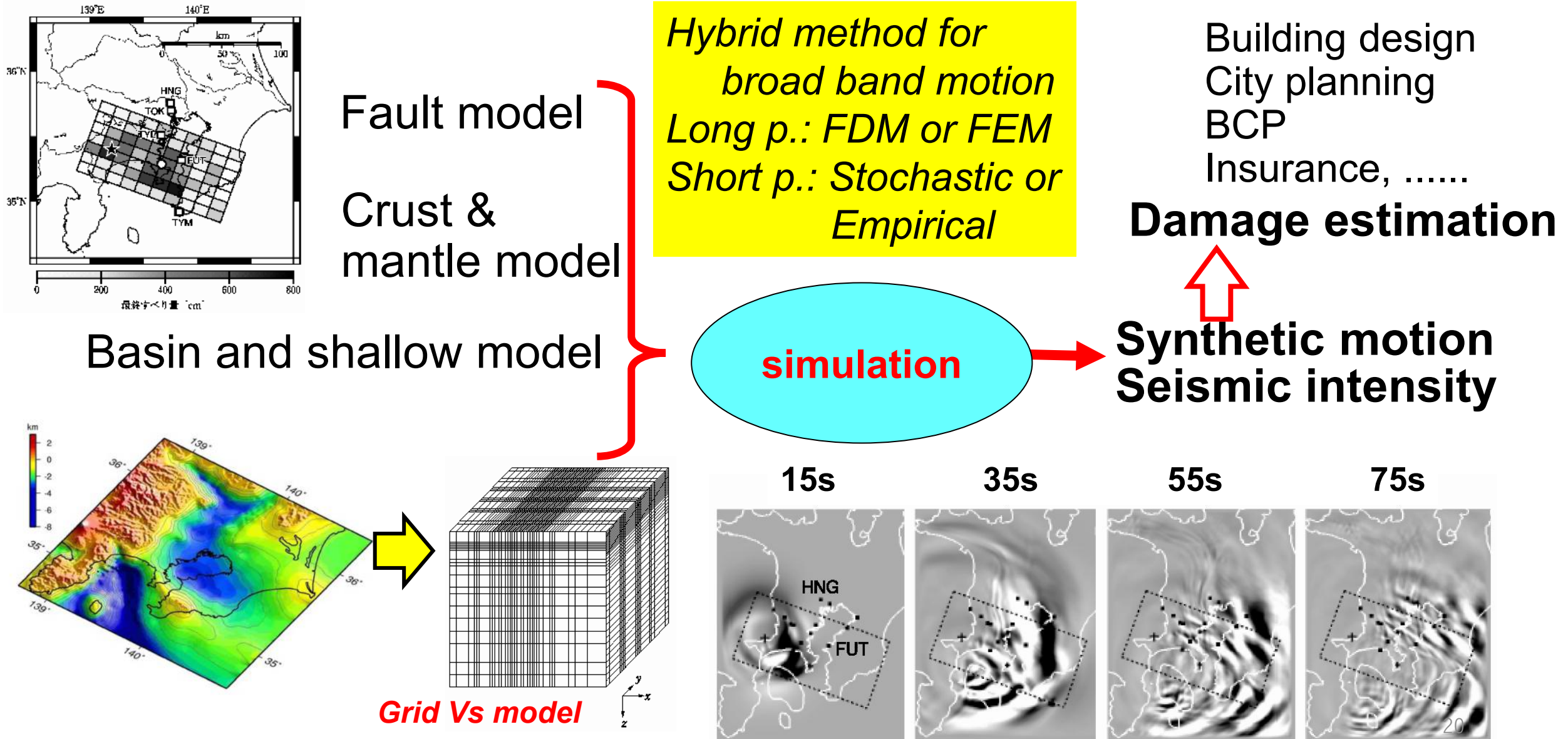
Middle and Large size
Array Observation
(Kanto Area: 440 points)
about 5 km intervals

Borehole data



Depth to top of layers of SD model
(NIED, 2020)

Prediction of strong ground motion for future large events



Prediction of long-period ground motion of mega earthquake (M8.9)

- Damage in wide area
- Casualty : 30,000-320,000
- Building damage : 0.1-2.3M

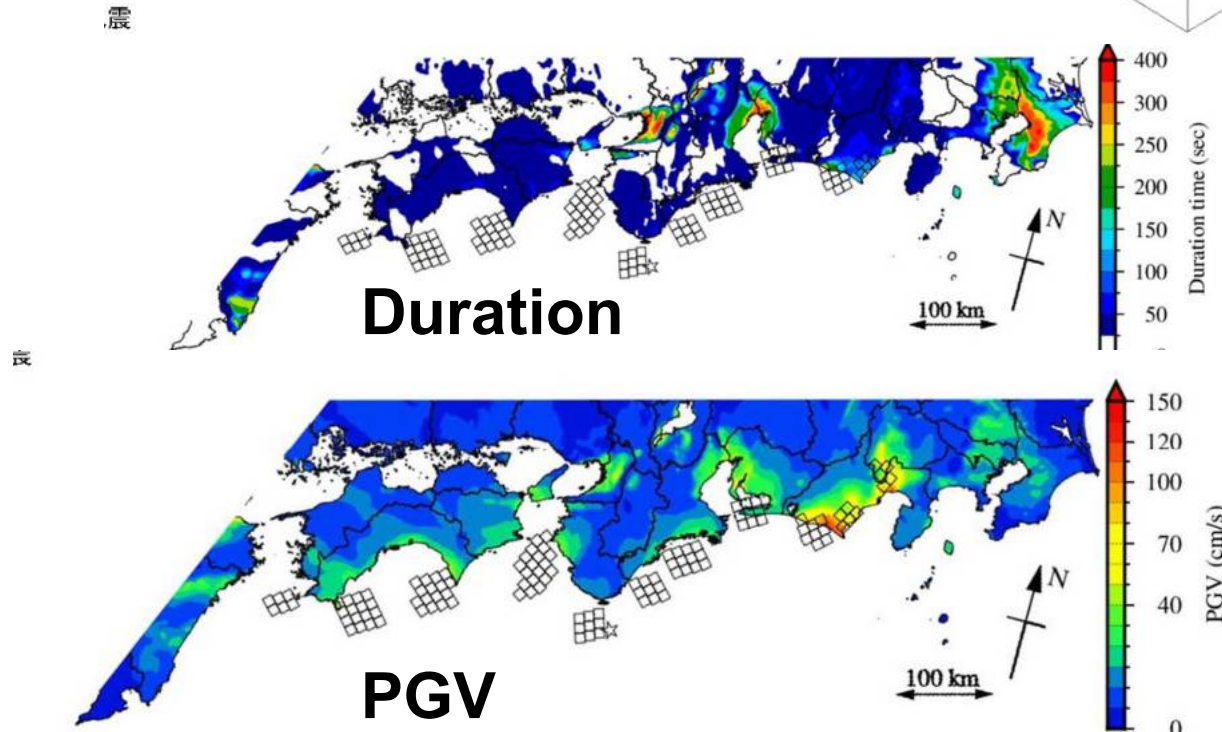
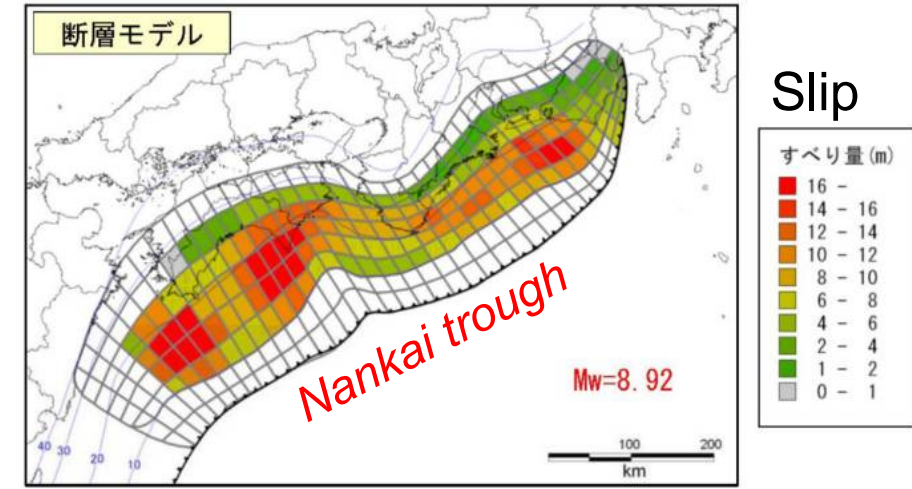
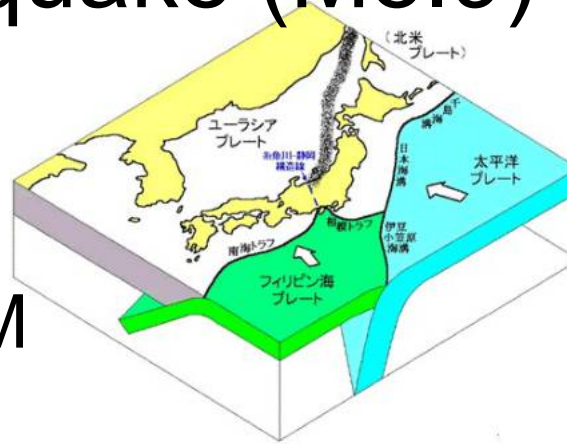


図 6-1. 地表の揺れ (最大速度)

(周期 2 秒～10 秒のバンドパスフィルタ処理[※]後)

(Cabinet office, 2015)

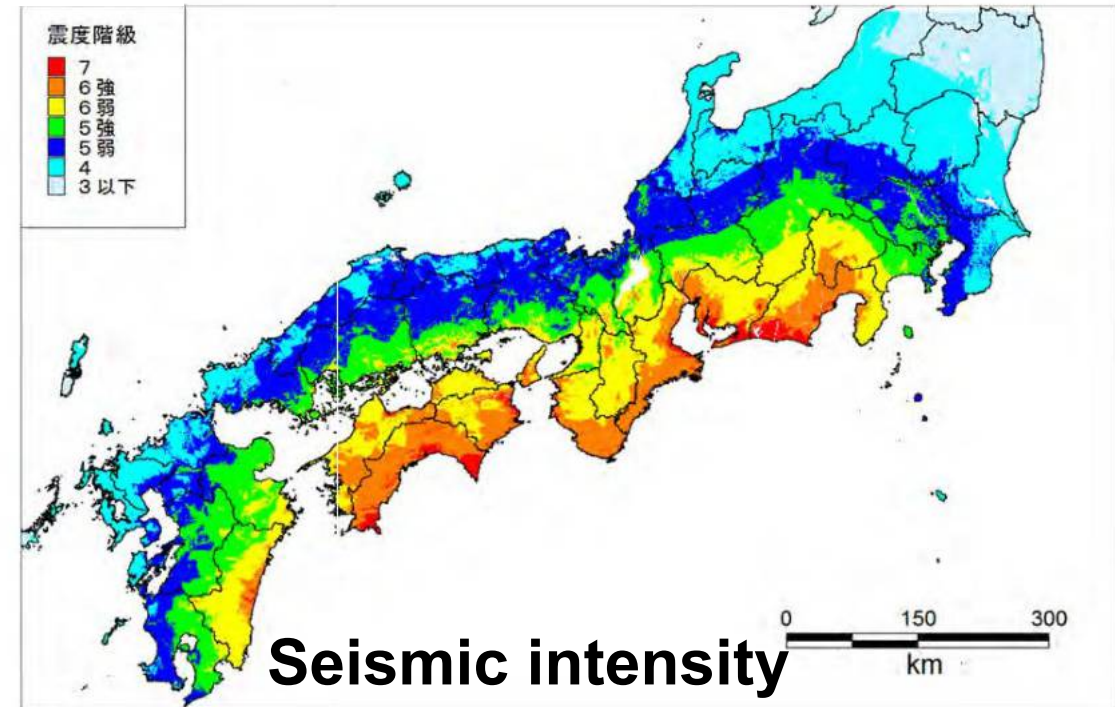
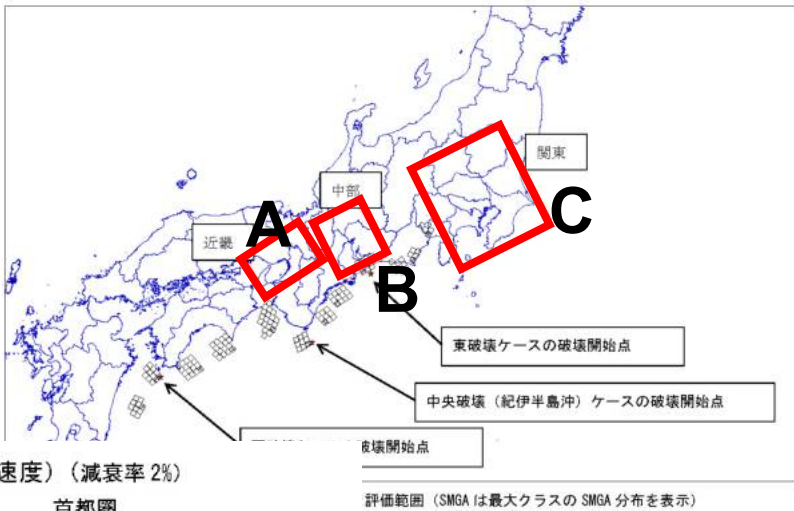


図5.6 震度の最大値の分布図

Earthquake response of buildings in three basins



PGD

PGA

最大クラスの地震による建物最上階の揺れ（最大変位）（減衰率 2%）
近畿圏 中部圏 首都圏

最大クラスの地震による建物最上階の揺れ（最大加速度）（減衰率 2%）
近畿圏 中部圏 首都圏

T=5s

T=5s

A

B

C

A

B

C

T=3s

T=3s

図 6-2 固有周期 5 秒の建物

図 6-1 固有周期 5 秒の建物

図 6-2-2 固有周期 3 秒の建物

図 6-1-2 固有周期 3 秒の建物

(Cabinet office, 2015)

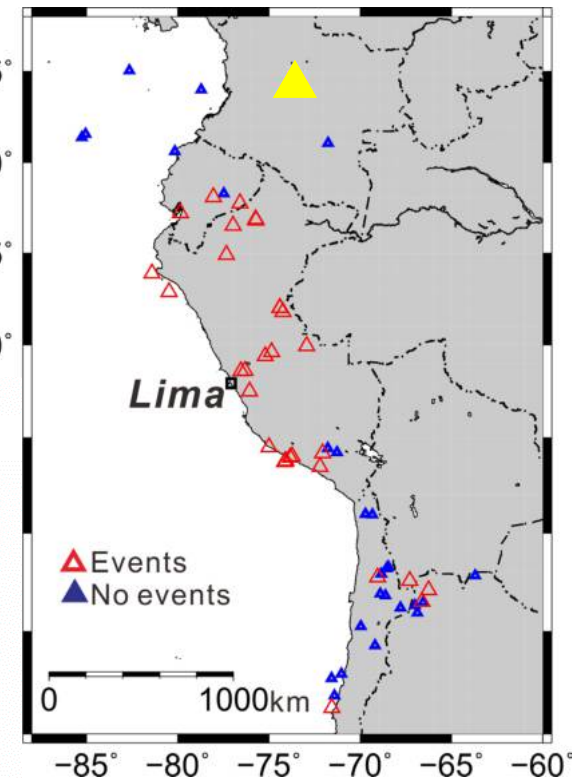
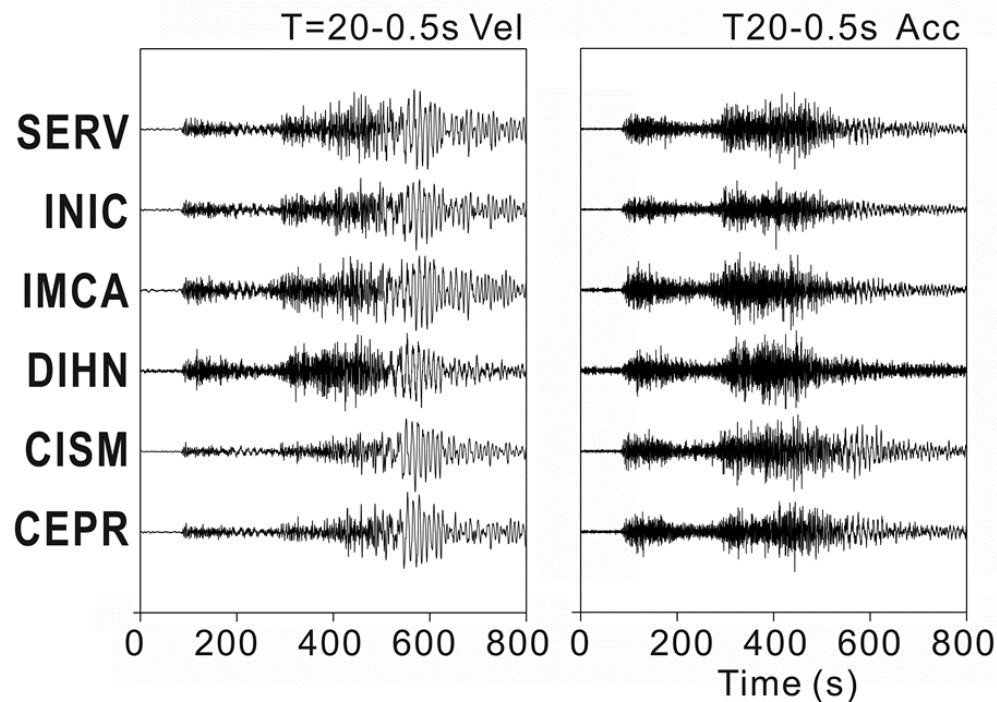
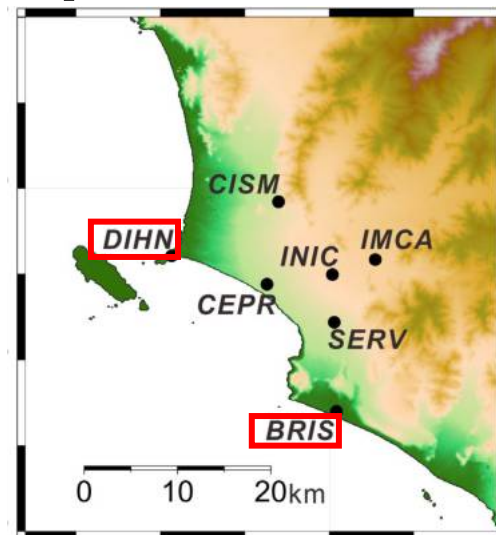
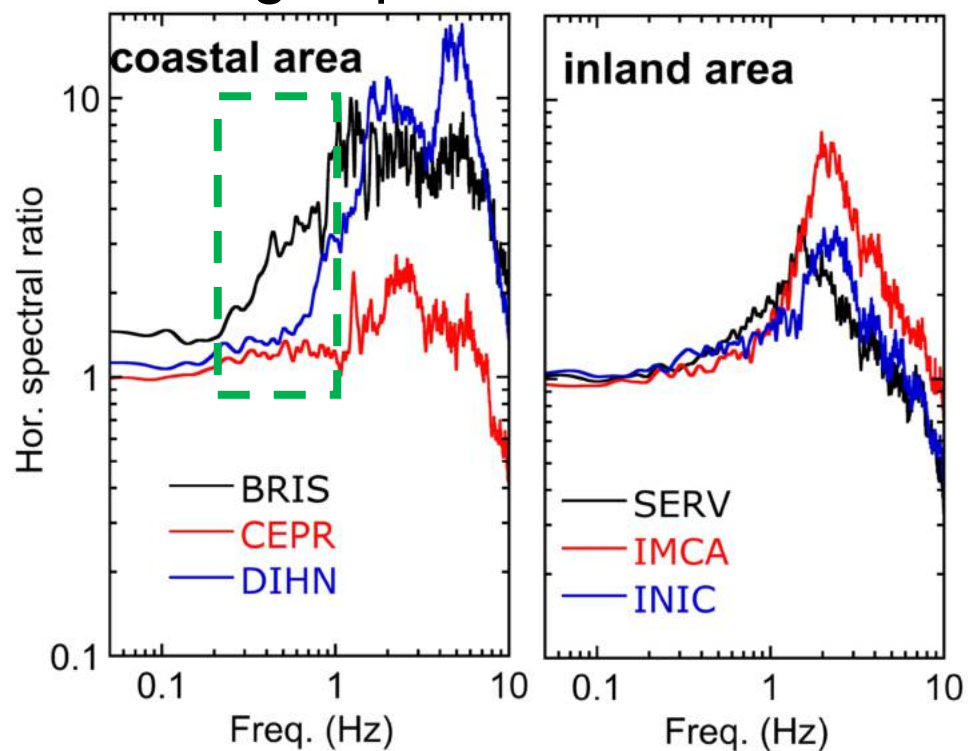
Long-period ground motion in Lima from SATREPS project

Observation for long-period motion in Lima

Long-period motion were observed in Lima during far-moderate events. Although amplitudes were not large, long-period motions at periods of 1 to 4 sec were dominant in coast area of Lima. We could establish Vs models of deep sediments in Lima for predicting long-period motion in SATREPS project.

2023/AUG/17
Event in Colombia
(M6.1, h10km, Δ 1862km)

Average spectral ratios to CISM



Conclusions

- High-rise buildings were often vibrated during distant large earthquakes. In Asian Mega cities, such as Tokyo, Manila, and Bangkok. Although damage was concentrated in non-structural parts, such damage avoided the rapid functional recovery of the affected buildings.
- Long-period motion at periods more than 1 second was dominated in the observed strong motion records by the contribution of surface waves amplified and generated in basins with deep sedimentary layers.
- Shaking of high-rise buildings due to distant large events is a common issue for Asian Mega cities. Researchers and engineers in seismology and earthquake engineering will collaborate on evaluating long-period motions of future large events for safety of large-scale structures.
- It is expected that long-period motion at periods of 1 to 4 seconds may be amplified in the coastal area of Lima during future large events.